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Arthur Cowper Ranyard, *Knowledge* and the reproduction of astronomical photographs in the late nineteenth-century periodical press

JAMES MUSSELL*

Abstract. The development of photographic reproduction in the late nineteenth century permitted images in a range of visual media to be published in the press. Focusing on the popular scientific monthly *Knowledge*, this paper explores the evidentiary status of reproductions of astronomical photographs. After succeeding its founder Richard Anthony Proctor in 1889, the new editor of *Knowledge*, Arthur Cowper Ranyard, introduced high-quality collotype reproductions into each number of the magazine. One of Ranyard's main interests was the structure of the Milky Way, evidence for which was only available through astronomical photographs. As Ranyard reproduced photographs in support of his arguments, he blurred the boundaries between the published collotype, the source negative and the astronomical phenomena themselves. Since each of these carried different evidentiary value, the confusion as to what, exactly, was under discussion did not go unremarked. While eminent astronomers disputed both Ranyard's arguments and the way in which they were presented, *Knowledge* disseminated both striking astronomical images and also a broader debate over how they should be interpreted.

When the astronomer and science writer Richard Anthony Proctor unexpectedly died in New York en route to Britain for a lecture tour in September 1888, many thought that his popular science monthly *Knowledge* would die with him.[1] However, the journal appeared as usual, but with a new editor and proprietor, Proctor's friend Arthur Cowper Ranyard. Proctor had founded *Knowledge* as a weekly in November 1881 to 'bring the truths, discoveries and inventions of Science before the public in simple but correct terms'.[2] On taking over the journal, Ranyard changed its publisher to W. H. Allen, but continued to edit it for a popular audience, even retaining its motto 'Simply Worded – Exactly Described'. But he made one more important change.

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1 See, for instance, E. Clodd and Capt. Noble, 'In Memoriam: Richard Anthony Proctor', *Knowledge* (1888), **11**, 265.

2 R. A. Proctor, 'To our readers', *Knowledge* (1881), **1**, 1–3, 3.

Ranyard was an astronomer who had impressed the astronomical community with his editorship of the 1879 eclipse edition of the *Memoirs of the Royal Astronomical Society*. His experience producing this large illustrated volume and his long-standing interest in photography gave him the expertise to introduce full-page, high-quality collotype reproductions of photographs in each issue of *Knowledge*.

Ranyard claimed that these reproductions were as good as the negatives from which they were created. He often appropriated them as the subjects of his own astronomical articles. Since the negatives had been created by leading astronomers, often using some of the finest equipment in the world, Ranyard was offering his readers unprecedented access to scientific resources that had only previously been available to a select few. However, as Ranyard used the reproductions to make arguments about the structure of the cosmos in the pages of *Knowledge*, he attracted criticism from astronomers who, comparing the reproductions with their negatives, disputed both their accuracy and their corresponding value as evidence. Caught between a desire to prove his astronomical theories to his readers and his need to advertise his high-profile correspondents, Ranyard allowed the disputes to unfold within the journal alongside the photographic reproductions. He died in 1894, but his brief tenure as editor of *Knowledge* featured not only some of the most strikingly reproduced photographs to appear at a time when photography was rare in the periodical press, but also a crucial discussion of the relative evidentiary value of photographs and their reproductions in the press. Carried out in a popular-science journal, this discussion concluded that the documents with the most evidentiary value were the photographic negatives that necessarily remained resolutely beyond its pages.

Richard Anthony Proctor, Arthur Cowper Ranyard and *Knowledge*

By the time of Proctor's death in 1888, *Knowledge* was a twenty-four-page sixpenny monthly that was published within a blue sixteen-page advertising wrapper. When the journal was launched in 1881 Proctor had intended it to be a cheap scientific weekly, similar in design to *Nature* but providing an alternative approach to science, aligned with that espoused in weeklies such as the *English Mechanic* with its lively correspondence columns.[3] But in 1885, pleading overwork, Proctor transformed the journal from a weekly to a monthly. The price had already been raised from twopence to threepence the previous year, and he now raised it to sixpence. He removed much of the correspondence and increased the pagination by two pages per issue. The decision made economic sense: as the paper size and printing block remained the same, over a month readers were actually receiving seventy-five per cent less content for a fifty per cent

3 B. Lightman, *Victorian Popularizers of Science*, Chicago, 2007, 325–35; *idem*, '*Knowledge* confronts *Nature*: Richard Anthony Proctor and popular science periodicals', in *Culture and Science in the Nineteenth-Century Media* (ed. L. Henson, G. Cantor, G. Dawson, R. Noakes, S. Shuttleworth and J. R. Topham), Aldershot, 2004, 199–210. For the *English Mechanic* see W. H. Brock, 'The development of commercial science journals in Victorian Britain', in *Development of Science Publishing in Europe* (ed. A. J. Meadows), Amsterdam, 1980, 95–122; J. Mussell, *Science, Time and Space in the Late Nineteenth-Century Periodical Press*, Aldershot, 2007, 29–36.

reduction in price. But it also made sense in terms of the orientation of the journal. Bernard Lightman has suggested that the change in periodicity was a tacit admission that Proctor's 'little experiment in conducting an egalitarian popular science journal' had failed as it 'threatened to turn readers into editors'.[4] There was also a more practical reason. In 1884 Proctor had moved to the United States, settling at first in Missouri and then in Florida.[5] Although Edward Clodd acted as subeditor in London, Proctor still contributed the majority of content in each issue of *Knowledge*. The distances involved meant that the publication of timely copy, abreast of contemporary controversies within the pages of the magazine and beyond, was impossible. The more leisured pace of the monthly allowed Proctor to address more general subjects, whether astronomy or musings on his life across the Atlantic. However, this was at the cost of the vibrant participatory print model that had previously characterized the journal. As a monthly, *Knowledge* was closer to the model of the book, and Proctor reimagined readers in a passive role, consuming science much as they would consume other types of literary content.[6]

Although both Proctor and Ranyard were graduates of the University of Cambridge and had gone on to study law, they were not contemporaries. Proctor left Cambridge in 1860 and had given up the law by 1863, while Ranyard entered Pembroke College in 1865, graduated in 1868 and was called to the Bar at Lincoln's Inn in 1871. Proctor was by far the more experienced participant in nineteenth-century print culture, according to M. J. Crowe producing 583 essays over his lifetime, many of which provided the content for his fifty-seven books.[7] Unlike Proctor, whose pen had been his chief means of support since the failure of a business speculation in May 1866, Ranyard's career as a barrister, as well as a private income, allowed him

4 Lightman, '*Knowledge* confronts *Nature*', op. cit. (3), 208; *idem*, *Victorian Popularizers of Science*, op. cit. (3), 341–5. See also anonymous [Richard Anthony Proctor], 'Gossip', *Knowledge* (1885), **8**, 204–6, 204.

5 For Proctor in America see L. O. Saum, 'The Proctor interlude in St. Joseph and in America: astronomy, romance and tragedy', *American Studies International* (1999), **37**, 34–54.

6 This view of popular science – contested but widely held amongst nineteenth-century popularizers – retains currency today. For good overviews see S. Shapin, 'Science and the public', in *Companion to the History of Modern Science* (ed. R. C. Olby, G. N. Cantor, J. R. R. Christie and M. J. S. Hodge), London, 1990, 990–1007; P. J. Bowler and I. R. Morus, *Modern Science: A Historical Survey*, Chicago and London, 2005, 367–90; I. R. Morus, 'Replacing Victoria's scientific culture', *19: Interdisciplinary Studies in the Long Nineteenth Century* (2006), **2**, available at http://www.19.bbk.ac.uk (accessed 15 August 2008). For discussions of nineteenth-century popularization see S. Sheets-Pyenson, 'Popular science periodicals in Paris and London: 1820–1875', *Annals of Science* (1985), **42**, 549–72; B. Lightman, '"The Voices of Nature": popularizing Victorian science', *Victorian Science in Context* (ed. B. Lightman), Chicago and London, 187–211; A. Fyfe, *Science and Salvation: Evangelicals and Popular Science Publishing*, Chicago and London, 2004. For methodological and historiographic reflections see S. Hilgartner, 'The dominant view of popularization: conceptual problems, political uses', *Social Studies of Science* (1990), **20**, 519–39; R. Cooter and S. Pumfrey, 'Separate spheres and public places: reflections on the history of science popularization and science in popular culture', *History of Science* (1994), **32**, 237–67; B. Latour, *Science in Action*, Cambridge, MA, 1987, 46–59. Actual readers, of course, are not passive. See, for instance, A. Desmond, 'Artisan resistance and evolution in Britain, 1819–1848', *Osiris* (1987), **3**, 77–110; Cooter and Pumfrey, op. cit., 237–67.

7 M. J. Crowe, *The Extraterrestrial Life Debate 1750–1900*, Cambridge, 1986, 368. See also Lightman, *Victorian Popularizers of Science*, op. cit. (3), 300–7; R. Hutchins, 'Proctor, Richard Anthony (1837–1888)', *DNB*, available at http://www.oxforddnb.com/view/article/22838 (accessed 2 February 2007).

to dedicate his writing almost entirely to his science without worrying about remuneration.[8] He was a contributor to *Knowledge*, but his experience of publishing was mostly concentrated in specialist scientific publications, particularly the *Monthly Notices of the Royal Astronomical Society*, where nearly all of his published work appeared.[9] However, Ranyard had gained some experience of commercial publishing while briefly working on the staff of *Nature* in 1871 and 1872 and shortly afterwards on the eclipse edition of the *Memoirs of the Royal Astronomical Society*.[10] Instigated by the Astronomer Royal George Biddell Airy, this project was originally intended to include details of the eclipses of 1860, 1869 and 1870. When Ranyard assumed responsibility from Airy in 1871 he expanded its scope to include all observations since 1715. As the original diagrams and illustrations were in a variety of formats, Ranyard oversaw a complex process of reproduction and standardization to produce what Alex Soojung-Kim Pang has described as 'one of the few volumes that could serve as a tool for scientific research'.[11]

Ranyard's career in print prior to taking over *Knowledge* gave him a sound grasp of the production of text and image for the press but little experience of how science publishing might turn a profit. Sales of *Knowledge* had been declining since Proctor converted *Knowledge* into a monthly and, by the time of his death, had fallen to less than five thousand copies a month.[12] Ranyard's solution was to broaden the scope of the journal without altering its character. In his first address he promised that the 'ablest exponents of science' would 'contribute articles and letters to its pages, and more space than hitherto will be devoted to Physics and Physical Geography, and to Natural History, including Botany'. Although admitting that the 'space devoted to Astronomy must be somewhat curtailed', he reassured his readers that 'it will probably remain the leading feature of the magazine'.[13] Throughout his life Proctor had been an ardent controversialist. Ranyard largely avoided controversy during his scientific career and so remained on good terms with many of the influential scientists who had been offended by his predecessor.[14] As Lightman has suggested, what distinguished

8 See Crowe, op. cit. (7), 368–9; Lightman, *Victorian Popularizers of Science*, op. cit. (3), 300–2.

9 Ranyard published eighteen papers in the *Monthly Notices of the Royal Astronomical Society*. In 1882 his contributions to *Knowledge* were published together with those of Proctor, Clodd and A. Wilson as *Leisure Readings*, part of the Knowledge Library by Wyman and Sons.

10 For Ranyard's work with Lockyer see Royal Astronomical Society, Ranyard MS 1 (2), 50, 64.

11 A. Soojung-Kim Pang, 'Victorian observing practices, printing technology, and representations of the solar corona (1): the 1860s and 1870s', *Journal for the History of Astronomy* (1994), **25**, 249–74, 267. See also *idem*, *Empire and the Sun: Victorian Solar Eclipse Expeditions*, Stanford, 2002, 96–105.

12 Lightman, *Victorian Popularizers of Science*, op. cit. (3), 348.

13 A. C. Ranyard, 'To our readers,' *Knowledge* (1888), **12**, 1.

14 For Proctor clashing with Joseph Norman Lockyer see A. J. Meadows, *Science and Controversy: A Biography of Sir Norman Lockyer*, London, 1972, 96–103; Hutchins, op. cit. (7). For Proctor clashing with Edward Holden see W. W. Payne, 'The Holden–Proctor unpleasantness', *Sidereal Messenger* (1887), **6**, 192; D. E. Osterbrock, 'The rise and fall of Edward S. Holden: Part 1', *Journal for the History of Astronomy* (1984), **15**, 81–127, 87–9; W. Sheehan, *The Immortal Fire within: The Life and Work of Edward Emerson Barnard*, Cambridge, 1995, 122–3, 130. Ranyard, however, worked with Lockyer on *Nature*, collaborated with George Biddell Airy on the eclipse volume of the *Memoirs of the Royal Astronomical Society* and corresponded amicably with Holden. For Ranyard and Lockyer see Ranyard MS 1, op. cit. (10); for his role in the eclipse volume see Pang, 'Victorian observing practices', op. cit. (11), 249–74; for Ranyard and Holden

Knowledge from other cheap scientific weeklies was its original content. Ranyard could draw on a much wider pool of contributors, as well as exploit his contacts to introduce contributions from the leading scientists of the day.[15] By broadening the title's disciplinary reach while retaining the astronomy at its core, Ranyard hoped the journal could hold on to its existing readers while also attracting new ones, drawing on the work of other science writers to supplement his own astronomical contributions.[16]

Ranyard himself was not a popularizer. Most of his publications were in specialist journals of scientific research and he had no need to publish widely for a living. By expanding the contributors to *Knowledge*, Ranyard could leave the popularizations to them and concentrate on his own specialism, astronomy. Although Ranyard was keen to keep *Knowledge* afloat to provide an income for Proctor's widow and family, he also aimed to use it to establish a scientific voice for himself.[17] Ranyard was aware that a large component of his readership was not made up of practising scientists. These readers were necessary as purchasers both of the journal and, potentially, of the goods advertised in its pages (see Figure 1). To satisfy the requirements both of the popular audience that he inherited and of the expert audience he hoped to cultivate, Ranyard drew upon his experience in producing the eclipse edition of the *Memoirs* to improve the illustrations within the magazine. By introducing a more advanced form of photomechanical reproduction into the pages of *Knowledge*, Ranyard was able to put striking photographic images at the service of his authors that might also function as evidence for his own scientific research. The high-quality collotype reproductions that Ranyard published from 1889 distinguished *Knowledge* from its rivals by making scientific photographs available to its readers. However, the way they were used by Ranyard to intervene in astronomical disputes precipitated a debate about what would constitute scientific evidence.

Science, photography and photographic reproduction in the late nineteenth-century periodical press

Ranyard first signalled his interest in photomechanical reproduction to the readers of *Knowledge* in an untitled note published in March 1889. This note revealed that the illustrations accompanying an article entitled 'Automatic recording instruments at the Lick Observatory' published in January 1889 had been reproduced photographically

see Royal Astronomical Society, Ranyard MS 3, 1–2. In the latter case, Holden was particularly keen to provide Ranyard with some magic lantern slides for Proctor's wife so that he could demonstrate that 'Proctor himself took a very unjust view of my relations to him'.

15 Lightman, *Victorian Popularizers of Science*, op. cit. (3), 333–5.

16 There was a perceived market for both science writing and science writers as a result of the expansion of scientific education late in the century. See D. S. L. Cardwell, *The Organisation of Science in England*, London, 1972, 111–86, 161; R. M. Macleod, 'Resources of science in Victorian England', in *Science and Society 1600–1900* (ed. P. Mathias), Cambridge, 1972, 111–16; J. A. Lancashire, 'An historical study of the popularization of science in general science periodicals in Britain 1890–1939', unpublished Ph.D. thesis, University of Canterbury, 1988, 53–4.

17 See anonymous [W. H. Wesley], 'Obituary', *Monthly Notices of the Royal Astronomical Society* (1895), **55**, 198–201, 199. Ranyard also completed Proctor's magnum opus, *Old and New Astronomy*, which had just begun publication in parts after twenty-five years in preparation.

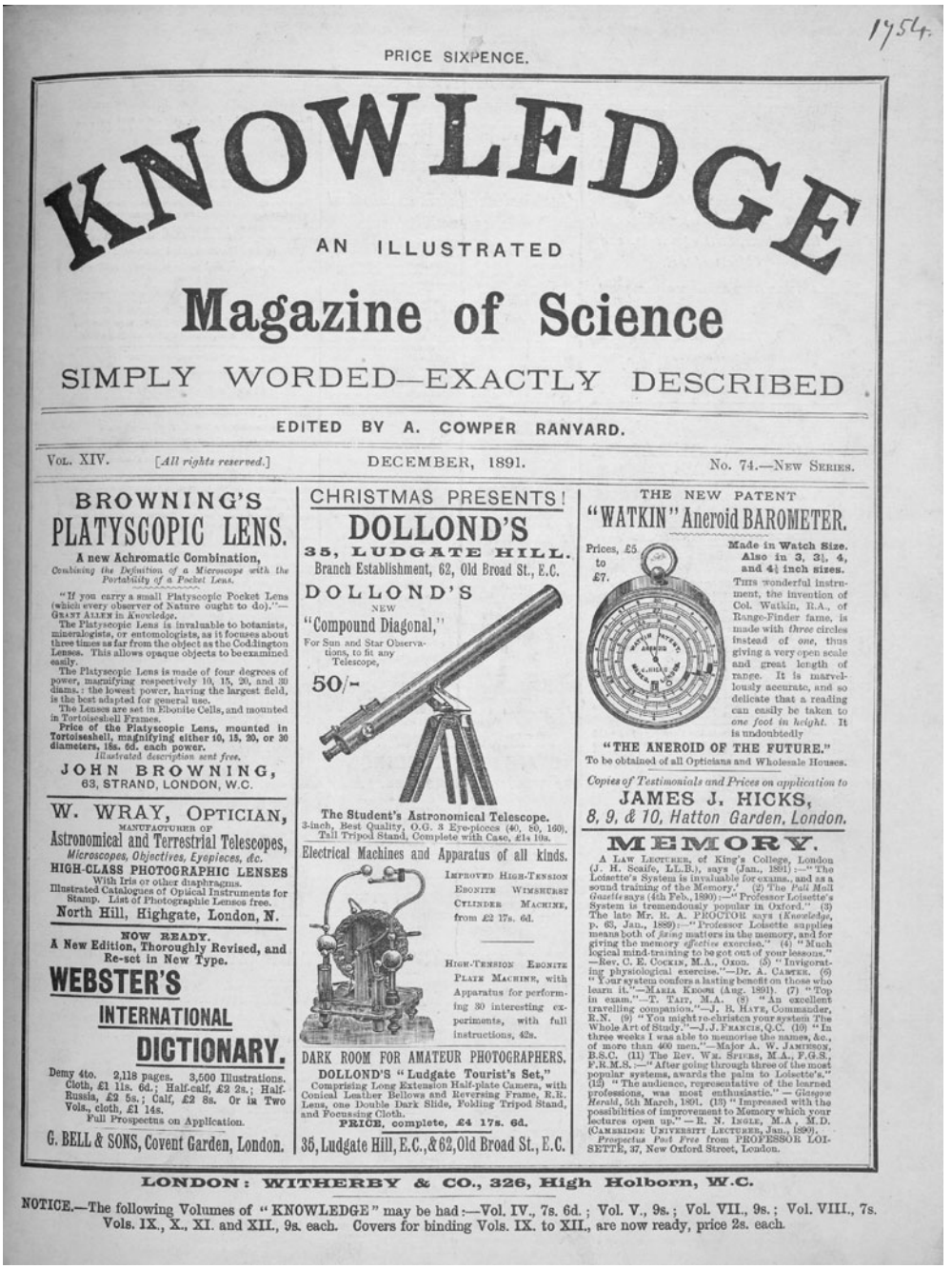

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Figure 1. Cover of *Knowledge*, **14**, December 1891. Copyright The British Library. All rights reserved. PP.1447.bb.

from an issue of *Engineering* of the previous August.[18] The majority of images in *Knowledge* were derived from wood engravings, but the presence of the occasional reproduced photograph or pen-and-ink drawing indicated to readers that it was likely that some of the other images had also been reproduced through photomechanical methods.[19] Photography had been used since the mid-1860s to transfer drawings and photographs onto blocks to be engraved, but it was not until the introduction of line-process work from Paris in the early 1870s that photomechanical reproduction began to compete with wood engraving as a means of producing blocks for printing.[20] Photomechanical reproduction, known as 'process' in the trade, was initially limited to the reproduction of line drawings. Although both cheaper and quicker than wood engraving, it could not capture the tonal contrasts of photographs or ink washes.[21] Half-tone reproductions, which could reproduce these effects, began to appear in the press from 1869, but the commercial application of the process did not become widespread until George Meisenbach patented his method in 1882.[22] To produce half-tones the source image (usually a photographic negative) was photographed through a screen marked with a finely-ruled grid: the tones on the source image were thus rendered as lines of graded dots that could then be etched into the plate using chemicals.[23] The idea of interposing a screen was not new; William Henry Fox Talbot had patented a process called 'phototypy' that used a black gauze screen in 1852. But Meisenbach's patent demonstrated how the technology might be practically applied.[24] In 1884 Meisenbach opened the first half-tone company in London and, when the industry began to see the results achieved in the United States using the improved screens produced by the Levy Brothers of Philadelphia, the number of companies began to grow. In 1884 there were six process companies listed in London. By the time Ranyard took over *Knowledge* there were fourteen and, just after his death in 1894, there were fifty-three.[25]

The use of process introduced a mixed economy of images into the periodical press. Illustrated weeklies such as the *Illustrated London News* or the *Graphic* began to use

18 A. C. Ranyard, untitled note, *Knowledge* (1889), **12**, 108.

19 Ranyard opts to reproduce a photographic portrait of Proctor in a memorial insert containing an obituary and an advert for *Old and New Astronomy*. See anonymous [A. C. Ranyard], 'The Late R. A. Proctor', *Knowledge* (1888), **12**, unpaginated.

20 G. Beegan, *The Mass Image: A Social History of Photomechanical Reproduction in Victorian London*, Basingstoke, 2008, 74–5. Carl Hentschel dates the use of photography to transfer images for hand engraving to 1866 and the arrival of line process to 1876. See C. Hentschel, 'Process engraving', *Journal for the Society of Arts* (1900), **48**, 461–74, 462 and 464. Walter Boutall suggests that line process arrived from Paris in 1871 as a result of the Franco-Prussian War. See W. Boutall, 'Technical education in relation to process engraving', *British Journal of Photography* (1897), **44**, 506–7, cited in Beegan, op. cit., 234. For a good (although hostile) overview of photomechanical methods, see T. Symmons, 'The present position of photography in relation to book and periodical illustration', *British Journal of Photography* (1892), **39**, 299–300 and 313–14.

21 Beegan, op. cit. (20), 73–5; Hentschel, op. cit. (20), 463–4.

22 D. Reed, *The Popular Magazine in Britian and the United States*, London, 1997, 30–1.

23 Reed, op. cit. (22), 28–30.

24 Hentschel, op. cit. (20), 463; Beegan, op. cit. (20), 75–6. See also M. Wolf, 'The line screen plates and their use', *British Journal of Photography* (1893), **40**, 574–6; and Pang, *Empire and the Sun*, op. cit. (11), 115–16.

25 Hentschel, op. cit. (20), 469.

line process from the mid-1870s to reproduce maps or line drawings and half-tone processes to reproduce works of art or photographs from the late 1880s.[26] High-quality wood engraving was capable of reproducing the effects of a range of media for printing, but process provided a mechanical means of reproducing the source image that did not need the skilled interpretation of the engraver. Gerry Beegan has described the shifts in wood engraving from 'tint', in which the engraver interpreted the original image to produce the best possible engraving, to 'facsimile', where the engraver simply reproduced the lines as they appeared.[27] Process quickly rendered human engravers redundant for facsimile work, but there remained a demand for expert engravers, especially as the blocks produced through process often required retouching.[28] However, prior to the demonstrable commercial success of the heavily illustrated *Strand Magazine* in 1891, the print trade in Britain remained cautious in its application of process.[29] It was difficult to implement, requiring significant changes to the ways in which images were produced and printed. The long exposures of five to ten minutes required to capture half-tones demanded a consistent and bright source of light and an environment free from vibrations. In addition, printing from the resulting blocks required high-quality art paper and expensive inks.[30] Aware of their deadlines and of the expense required to correct work, publishers and editors therefore often published images they feared would appear of poor quality to readers.[31] There were also concerns about the novelty of the images, particularly their perceived lack of artistry. In a paper delivered to the Society of Arts in 1891, Carmichael Thomas, editor of the *Graphic*, remarked that certain American publications 'are not only giving up the wood-engravers, but they are giving up the artists as well'. For Thomas, their appearance was 'most terribly monotonous and devoid of artistic treatment'. However, he recognized that sacrificing the mediating artist gave the image different conditions of truthfulness. 'If I were to show you a sketch in which the old lady who keeps cows in St. James's-park was seen putting water into the milk cans', he wrote, 'you might say it was made up; but when I place before you a photograph of such a proceeding, you must then admit, although all your better feelings are rudely shocked by the revelation, that it is true.'[32] It was the potential of the half-tone to reproduce the verisimilitude of photography that made it of interest to Ranyard. Although editors such as Thomas might have concerns about the lack of artistry in photomechanical reproduction, this same lack seemed to guarantee that the process was mechanical, effacing human intervention and so eliding the difference between the original photograph and its reproduction in the pages of the magazine.[33]

26 See Hentschel, op. cit. (20), 469–70; Reed, op. cit. (22), 34–5.

27 Beegan, op. cit. (20), 56–71.

28 See C. Thomas, 'Illustrated journalism', *Journal of the Society of Arts* (1891), **39**, 173–85, 177–8.

29 For the impact of the *Strand Magazine* see R. Pound, *The Strand Magazine 1891–1950*, London, 1966; Reed, op. cit. (22), 95–8; K. Jackson, *George Newnes and the New Journalism in Britain, 1880–1910*, Aldershot, 2001; Mussell, op. cit. (3).

30 Reed, op. cit. (22), 28–9. For a description of the *Graphic*'s line process, see Thomas, op. cit. (28), 183.

31 See Hentschel, op. cit. (20), 469–70.

32 Thomas, op. cit. (28), 178.

33 For mechanical objectivity as a negative reflex of subjectivity see L. Daston and P. Galison, 'The image of objectivity', *Representations* (1992), **40**, 81–128, 82–3.

Ranyard did not oversee the reproductions in *Knowledge* directly, but instead experimented with a number of firms before settling for the Direct Photo Engraving Company from September 1889.[34] Ranyard was an experienced photographer and an expert reader of astronomical images. Not only did he edit the eclipse edition of the *Memoirs*, but he also took part in eclipse expeditions in 1872, 1878 and 1882 with the specific goal of undertaking photographic work. At his death in 1894 he had obtained a spectroheliograph for further study of the solar corona.[35] The photograph was well established within astronomical practice as a source of evidence and a scientific instrument in its own right. Photography had been closely connected with astronomy since 1839 but with the growth of spectroscopy and the development of the gelatine-based dry plate in 1871 it could now provide different types of information from that obtained by the eye at the eyepiece.[36] In stellar astronomy recent photographs of nebulae by Isaac Roberts, A. A. Common and Paul and Prosper Henry so thoroughly demonstrated the efficacy of photography for the study of these objects that they threatened to supersede previous work while opening up whole new areas of research.[37] However, more significant was the mechanical and distributed nature of the photographic process. As Agnes M. Clerke noted, writing anonymously in the *Edinburgh Review* in 1887, photography produced objects that recorded the cumulative traces of light over an exposure in portable form through a repeatable process.[38] The sensitivity of the plates, coupled with the division of labour that the process entailed, offered a new way of producing data that, in

34 The Direct Photo Engraving Company was established in 1881 as the Direct Photo Litho and Metallo Gravo Printing Company Ltd. It was taken over in 1883 and went into liquidation in 1898. They were based in offices on Farringdon Street but, at the time of their liquidation, had opened studios in Barnsbury, North London. Such a move to the suburbs was common for process firms as their works were disturbed by the vibrations from the underground railway. The Direct Photo Engraving Company was financially unstable, pursuing court cases against the publishers Newnes and Beeton and losing much business after the departure of Carl Hentschel to set up his own firm in 1888. See anonymous, 'Markets – Saturday', *Birmingham Daily Post*, 4 April 1881, 6; anonymous, 'In liquidation – re. the Direct Photo Engraving Company, Ltd.', *Glasgow Herald*, 8 October 1898; both from *19th Century British Library Newspapers* (accessed 22 August 2008). See also the account of *Direct Photo Engraving Ltd and another* vs *Hentschel and another* in *The Times*, 22, 23, 24 and 25 March 1888.

35 Anonymous [W. H. Wesley], op. cit. (17), 199.

36 For the early history of photography see L. J. Schaaf, *Out of the Shadows: Herschel, Talbot, and the Invention of Photography*, London, 1992, 1–23. For the development of astronomical photography see H. C. Wilson, 'Astronomical photography', *British Journal of Photography* (1892), **39**, 617–18; E. E. Barnard, 'The development of photography in astronomy', *Science* (1898), **8**, 341–53; D. Norman, 'The development of astronomical photography', *Osiris* (1938), **5**, 560–94; G. de Vaucouleurs, *Astronomical Photography: From the Daguerrotype to the Electron Camera*, London, 1961, 13–68; H. Rothermel, 'Images of the sun: Warren De La Rue, George Biddell Airy and celestial photography', *BJHS* (1993), **26**, 137–69; Pang, 'Victorian observing practices', op. cit. (11); and A. Soojung-Kim Pang, 'Victorian observing practices, printing technology, and representations of the solar corona (2): the 1880s and 1890s', *Journal for the History of Astronomy* (1995), **26**, 63–76; Sheehan, op. cit. (14), 264–6; J. Tucker, *Nature Exposed: Photography as Eyewitness in Victorian Science*, Baltimore, 2005.

37 Pang, *Empire and the Sun*, op. cit. (11), 108. See also anonymous [A. M. Clerke], 'Sidereal photography', *Edinburgh Review* (1888), **168**, 23–46, 40.

38 Anonymous [A. M. Clerke], op. cit. (37), 24, 35. For Clerke see B. Lightman, 'Victorian popularizers of science: from reverent eye to chemical retina', *Isis* (2000), **91**, 651–80, 671–9; *idem*, *Victorian popularizers of Science*, op. cit. (3), 469–88; M. T. Brück, *Agnes Mary Clerke and the Rise of Astrophysics*, Cambridge, 2002.

turn, would lead to 'a new birth of knowledge regarding the structure of the universe'.[39] Although great skill, and a large array of specialist equipment, were necessary to produce high-quality astronomical photographs, the process appeared to be a passive one in which the 'stars would henceforth register themselves'.[40]

This is why Ranyard's decision to foreground the method of reproduction in an article about the instruments within the Lick Observatory is significant. Like the instruments within the observatory, photography had the potential to produce objective, quantitative data, but only when regulated by skilled practitioners in suitable scientific locations.[41] High up on Mount Hamilton in California, the Lick Observatory brought together capital, expertise and an array of world-class equipment within an institutional structure at a site selected for its viewing conditions.[42] Although the thirty-six-inch refractor in its South Dome was the largest telescope in the world, it was not so much the presence of telescopic power but rather the combination of resources that resonated with the wider astronomical community. Ranyard had already published an illustrated article about the Lick Observatory in *Knowledge* in December 1888 and he excused publication the next month of an article on 'Automatic recording instruments of the Lick Observatory' by suggesting that many of the instruments illustrated 'are of so simple a character that they can be easily made by amateurs'.[43] By drawing the attention of his readers to the method through which the illustrations to the article were reproduced, Ranyard offered his readers an insight into the production of his images in the same way that the articles offered them an insight into the workings of the instruments. The article and its accompanying illustrations granted access to the exclusive space of the Lick Observatory, but the reflexive interest in the images, by foregrounding the method of their reproduction, might also offer access to the institutionally ratified documents that were produced within its walls.

Ranyard's use of photographic reproduction was therefore explicitly political. Although astronomical photography was practised widely across the astronomical community, those photographs deemed to have evidentiary value were increasingly the products of well-resourced institutions such as the Lick Observatory. As a result, many of those amateurs who had participated fully within the science found that they were excluded from photographic work because of its technical requirements.[44] In Britain such exclusions mapped onto larger divisions in the science. In October 1890 the British Astronomical Association (BAA) was founded to provide an organizational body for

39 Anonymous [A. M. Clerke], op. cit. (37), 41.

40 Anonymous [A. M. Clerke], op. cit. (37), 34.

41 Daston and Galison, op. cit. (33), 83. See also S. Schaffer, 'Astronomers mark time: discipline and the personal equation', *Science in Context* (1988), **2**, 115–45.

42 F. J. Neubauer, 'A short history of the Lick Observatory, Part 1', *Popular Astronomy* (1950), **58**, 201–22; H. Wright, *James Lick's Monument: The Saga of Captain Richard Floyd and the Building of the Lick Observatory*, Cambridge, 1987; Osterbrock, op. cit. (14), 85–93; Sheehan, op. cit. (14), 97–123.

43 A. C. Ranyard, 'Automatic recording instruments of the Lick Observatory', *Knowledge* (1888), **12**, 58. The previous article is anonymous [A. C. Ranyard], 'The Lick Observatory', *Knowledge* (1888), **12**, 34–7.

44 See, for instance, the Earl of Rosse's report to the Royal Astronomical Society in 1890. Anonymous, 'Report of the Council to the Seventieth Annual General Meeting of the Society', *Monthly Notices of the Royal Astronomical Society* (1890), **50**, 141–264, 211.

amateur astronomy.[45] In his first presidential address Captain William Noble recognized the necessity for a division of labour in observational astronomy, as its scope had 'become so illimitable that the individual observer must confine himself to a very circumscribed area of it if he is to do any useful work at all'.[46] Noble was no supporter of the endowment of research but, as John Lankford has noted, his address acknowledged the impact that institutions like the Lick Observatory were having upon the organization of astronomy.[47] Noble disputed the idea that the BAA was a rival to the Royal Astronomical Society (RAS), stressing that most of its executive members were also Fellows of the society.[48] As the RAS had been strongly identified with the grand amateur tradition in British science, such overlap not only was inevitable but also reinforced the society as the source of astronomical authority and leadership.[49] More significant than the presence of Fellows of the RAS on the council of the BAA, however, was the presence of professional astronomers. For instance, the new society had largely come into existence through the industry of Edward Maunder, then employed in the Solar Section at the Royal Observatory, who also became the editor of the BAA's journal. Also on the council was his colleague Edwin Dunkin, who had been chief assistant at Greenwich since the retirement of Airy in 1881. The presence of salaried astronomers on the council of the BAA demonstrates how malleable were the categories of amateur and professional in the period, but it also indicates the reconfiguration of authority then under way. The BAA was intended to provide an organizational structure for amateur astronomy that would enable it to contribute usefully to the science as a whole.[50] In so doing, it reconfigured the extant but unstable terms of amateur and professional into a hierarchical relation: the astronomical elite was institutionalized as professionals, and the grand amateur aligned alongside the hobbyist and the dilettante.

The circulation and interpretation of images took part in this division of labour. In 1890, the very same year, the director of the Lick Observatory, Edward Holden, celebrated the photographic resources at his disposal in a paper published in the *Monthly Notices of the RAS*. Holden boasted of the quality of his lunar photographs, so accurate that it was 'practicable to see the lunar surface under excellent definition … whenever one pleases and as long as one pleases'. The photographic positives not only substituted for direct telescopic observations but, as Clerke had argued in the *Edinburgh Review*, actually surpassed them by allowing the observer to observe whenever he or she wished. But whereas Clerke imagined astronomers dividing the production and analysis of photographs between themselves according to their interests, Holden believed that it

45 For the foundation of the BAA see W. H. S. Monck, 'An Amateur Astronomers' Association', *English Mechanic* (1890), **51**, 445; E. Brown, 'An Amateur Astronomers' Association', *English Mechanic* (1890), **51**, 463; A. Chapman, *The Victorian Amateur Astronomer*, Chichester, 1998, 243–75.

46 Anonymous, 'Report of the meeting of the Association held November 26, 1890', *Journal of the British Astronomical Association* (1890), **1**, 49–58, 50.

47 J. Lankford, 'Amateurs versus professionals: the controversy over telescope size in late Victorian science', *Isis* (1981), **72**, 11–28, 22. For Noble's reference to the Lick Observatory see anonymous, op. cit. (44), 53.

48 Anonymous, op. cit. (46), 50. For the list of those involved see anonymous, 'Officers and Council', *Journal of the British Astronomical Association* (1890), **1**, 8.

49 Chapman, op. cit. (45).

50 Lankford, op. cit. (47), 11.

was 'not possible with the force at the disposition of the Lick Observatory to undertake more than the production of the materials for such a study' and so envisaged 'some lonely and athletic student … devoting two or three years to their thorough and exhaustive study'.[51] So not only would well-resourced institutions such as the Lick Observatory be responsible for the production of astronomical images, but they would also oversee their distribution and subsequent analysis.

Photomechanical reproduction, in particular the half-tone process that was being experimented with in the late nineteenth-century periodical press, allowed the image to be separated from its material carrier, liberating it from the context of its photographic production and consumption.[52] For Ranyard this offered the means to democratize what were otherwise scarce images, removing them from the closed network of astronomers within which they circulated and instead reproducing them for the readers of his magazine. This transformed the context for their interpretation from the communication media of specialist science such as the scholarly journal, meeting of learned society or private correspondence, to a public commodified space in which the readers were unknown. What was at stake for Ranyard was the transposition of scientific processes of image production and reproduction into the journalistic space of magazine publication. As Gerry Beegan has noted, the half-tone process did not produce an exact replica of the image. Not only were they marked by the manner of their reproduction (as, for instance, in the way they rendered the image as a series of dots) but they were also recontextualized by the new print objects through which they were reproduced.[53] For Ranyard to make claims about astronomical phenomena on the basis of the reproductions in *Knowledge*, he had to convince readers, whether astronomers or not, that the reproductions accurately resembled the phenomena they represented. As astronomical photographs often revealed details that were not visible through the eyepiece, only the photographic negatives were ratified as scientific documents, and these, of course, could not be published. However, neither photography nor the half-tone process was entirely mechanical. Rather, the objectivity that warranted astronomical photography was based upon the accepted interventions of equipment, people and processes. The balance of this paper describes how Ranyard attempted to establish photomechanical reproduction as an extension of astronomical photography, permitting the stars to register themselves both upon the negative and upon the page of *Knowledge*.

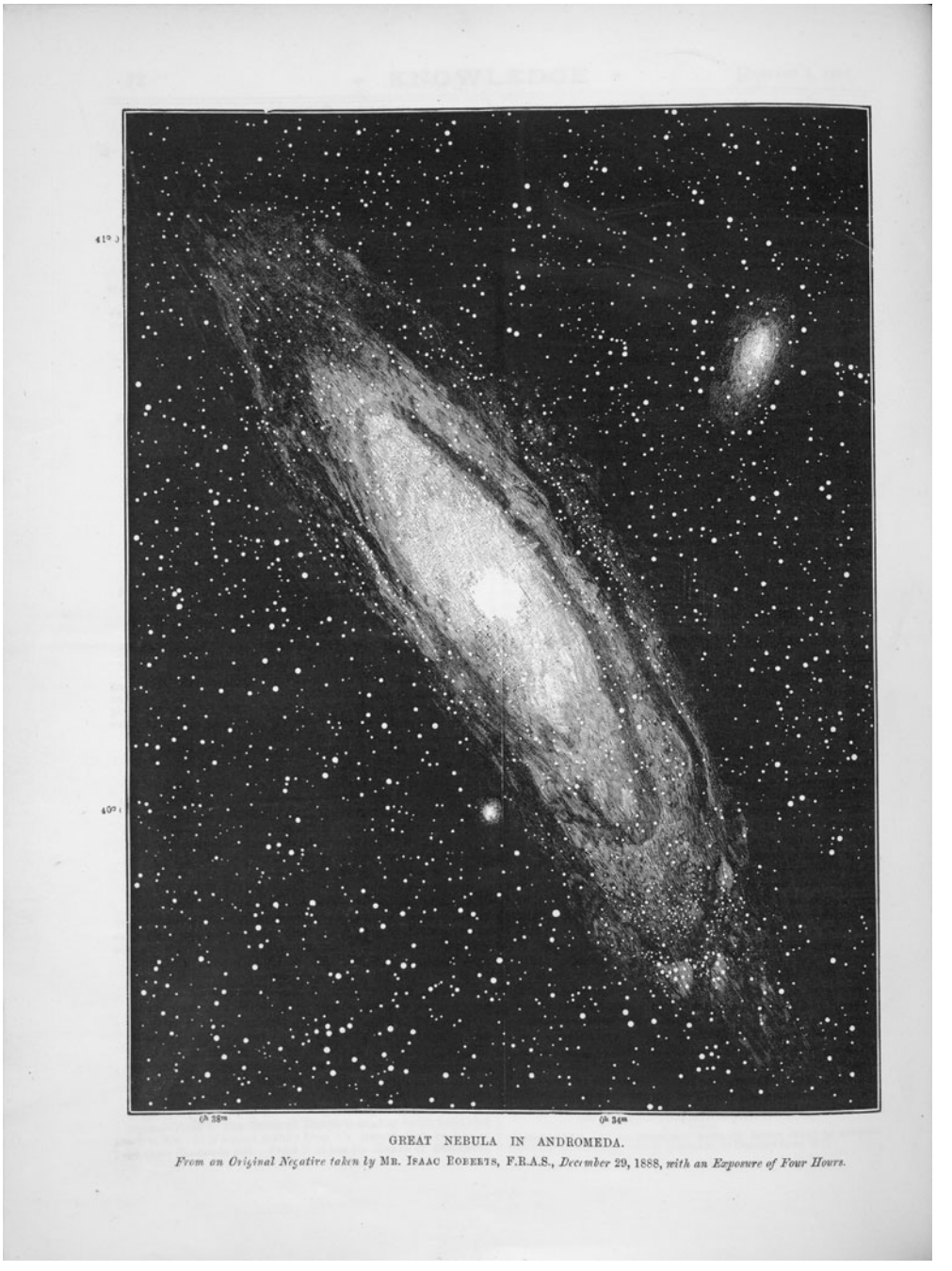
The use of collotype reproductions in *Knowledge*: Isaac Roberts's photograph of the nebula in Andromeda

In February 1889 Ranyard published an article in *Knowledge* entitled 'The Great Nebula in Andromeda'. It discussed the structural details revealed by Isaac Roberts's famous photograph of 29 December 1888. The article was accompanied by a full-page wood engraving based upon a drawing by W. H. Wesley of the photograph (Figure 2)

51 E. S. Holden, 'The photographic apparatus of the great equatorial of the Lick Observatory', *Monthly Notices of the RAS* (1890), **50**, 101–6, 106.

52 Beegan, op. cit. (20), 13.

53 Beegan, op. cit. (20), 15–16.



GREAT NEBULA IN ANDROMEDA.

From an Original Negative taken by Mr. Isaac Roberts, F.R.A.S., *December* 29, 1888, *with an Exposure of Four Hours.*

Figure 2. 'Great Nebula in Andromeda', *Knowledge*, **12,** February 1889, facing p. 75. Copyright The British Library. All rights reserved. PP.1447.bb.

and some explanatory diagrams. Ranyard signalled the newsworthiness of the photograph to his readers, reminding them that the spiral structure of the nebula 'was not recognized until a few weeks ago, when the remarkable photographs of Mr Isaac Roberts came as a revelation to the astronomical world'.[54] Although the article was written in a popular style, recounting the history of the object from the tenth century to the present, the real subject under discussion was the structure revealed by the photograph. This article was the second that Ranyard contributed to an 1889 series exploring the structures in nebulae revealed by Isaac Roberts's photographs.[55] This particular photograph was important, Ranyard argued, because it was the first to provide photographic evidence of structure: previous attempts (it 'had already been photographed many times') only captured the brightest portions and observers could often see more 'nebulous light' at the eyepiece.[56] Later that year, in an article in November 1889 on Otto Boeddicker's Milky Way drawings, Ranyard speculated about the existence of 'streams of opaque matter, dust clouds or fog-filled space' that obscured the light from the bright streams of the Milky Way.[57] This was a pet hypothesis of Ranyard's; although he did not allude to it directly in his series of articles on nebulae, his emphasis on the necessity of accurate photographic reproductions of structure seems to suggest that his thoughts were tending in this direction.[58]

Since the article was an attempt to elucidate nebulous structure in Andromeda, its success rested on the willingness of Ranyard's readers to accept his interpretation of the image. To convince them, Ranyard attempted to establish the evidentiary value of both Roberts's negative and the engraving that he had made from it:

> Mr Roberts has kindly entrusted me with the loan of one of his negatives, from which Mr Wesley has made a most careful drawing that has been used for the preparation of the image on the opposite page. The drawing has been made from a single photograph, but it should be mentioned that the nebulous structure shown on this photograph has been confirmed by another long-exposure photograph of the nebula which Mr Roberts obtained.[59]

The existence of a second photograph demonstrated that the nebulosity was not restricted to the one image, so could not be attributed to a temporary phenomenon in the nebula or the way in which the plate had been developed.[60] Ranyard hoped that the name of his draughtsman, W. H. Wesley, would testify to the quality of the engraving.

54 A. C. Ranyard, 'The Great Nebula in Andromeda', *Knowledge* (1889), **12**, 75–7, 75. See also Vaucouleurs, op. cit. (36), 57.

55 The previous article was on the Pleiades and published in January 1889. See A. Cowper Ranyard, 'The Great Nebula in the Pleiades', *Knowledge* (1889), **12**, 68–9. The third article, on Orion, is discussed below.

56 Ranyard, op. cit. (54), 75.

57 'A. C. R.' [Arthur Cowper Ranyard], 'Drawings of the Milky Way', *Knowledge* (1889), **13**, 6–7. See also Sheehan, op. cit. (14), 266–7.

58 See, for instance, Ranyard's remarks at the RAS after A. A. Common presented his photograph of the nebula in Orion in March 1883. Reported in anonymous, 'Scientific notes', *Graphic* (1883), **27**, 342, within *19th Century British Library Newspapers* (accessed 22 August 2008). For Common's paper and a diagram of the photograph see A. Ainslie Common, 'Note on a photograph of the Great Nebula in Orion and some new stars near θ Orionis', *Monthly Notices of the Royal Astronomical Society* (1883), **43**, 255–7.

59 Ranyard, op. cit. (54), 75.

60 For more on the spatial–temporal limitations of photography see Rothermel, op. cit. (36), 137–69; Pang, 'Victorian observing practices', op. cit. (12), 256.

Wesley had worked with Ranyard on the eclipse edition of the *Memoirs*, was assistant secretary at the RAS and had a strong reputation as a producer of astronomical images.[61] But when compared to a mechanical process such as that used by Roberts to obtain his photograph, Wesley's drawing and the resulting engraving could not but highlight the indispensable human mediation between the astronomical object and the image. The engraving, in particular, was also unsuitable for the representation of the subtle gradations of nebulosity, as it was dependent on black-and-white lines. Similar problems affected the diagrams. Ranyard conceded that there were some stars so small that they barely appeared on Roberts's image and, as they were so numerous, Wesley had not included them on the diagrams either. Ranyard defended the diagrams in the same way he defended the engraving, telling readers that, despite the omissions, their preparation had taken Wesley 'many days'. By repeatedly naming Wesley in the article, Ranyard attempted to defend his role as mediator. Yet this defensive strategy ultimately associated mediation with deformation, defining the photograph as authoritative source and the engraving and diagrams as imperfect surrogates.[62]

In the next number of *Knowledge* in March 1889, Ranyard attempted to allay doubts about the accuracy of the engraving by providing the image as a half-tone 'to compare with and check the woodcut given in our last number' (Figure 3).[63] This image was prepared from a paper photograph dated 30 December 1889, the night after the photograph reproduced in *Knowledge* in the previous issue. This 'new process' complemented the more traditional method of drawing and engraving by providing a way of bringing the image to the page that did not require human interpretation. Comparing the two, Ranyard alerted readers to a white line down the centre of the engraving caused by the slight misalignment of the two blocks from which the engraving was composed. He also pointed out that to make the image lighter the engraver had inserted some white dots that might easily be mistaken for stars. Despite these problems, he concluded that the engraving provided 'a very satisfactory representation of the original negative'.[64] However, the photographic reproduction was also imperfect, as it lacked some of the fainter stars and neither method captured all the detail of the stellar nucleus. In comparing the two methods, Ranyard repeated that it was the impersonal mechanical aspect of photography that granted it evidentiary value. In using the photographic reproduction to 'check' the engraving, he asserted that such criteria should also be applied to the means of reproduction. Although neither method was perfect, only photographic methods of reproduction could potentially reproduce the objectivity of an image, as they seemed to dispense with human mediation.

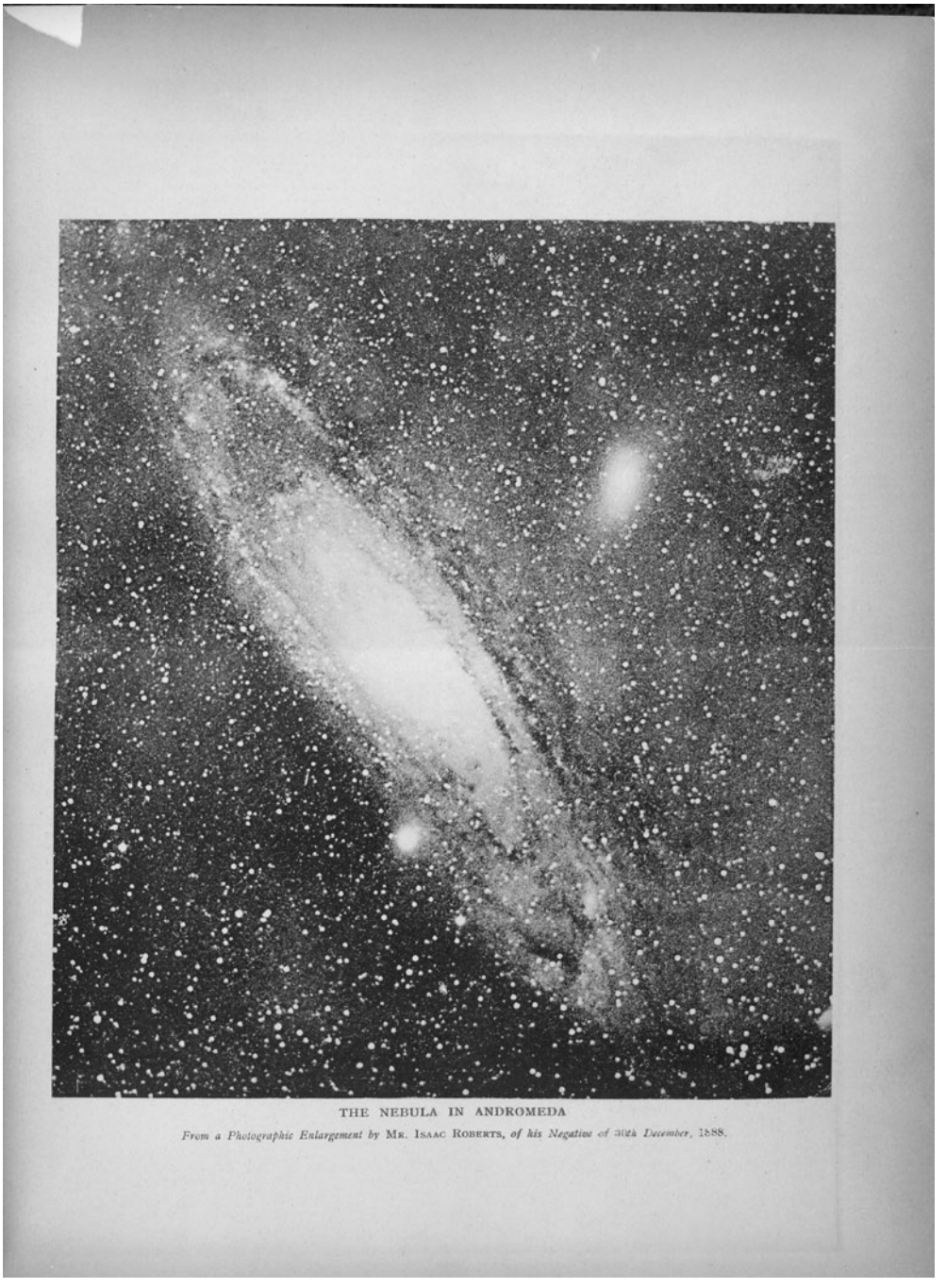
Following the March 1889 issue in which Ranyard first alerted his readers to his use of photographic methods to reproduce the illustrations for 'Automatic recording instruments at the Lick Observatory', he published two full-page collotype reproductions in each number of *Knowledge*. The collotype process used plates treated with a film of

61 B. J. Becker, 'Priority, persuasion, and the virtue of perseverance: William Huggins's efforts to photograph the solar corona without an eclipse', *Journal for the History of Astronomy* (2000), **31**, 223–43, 230.

62 Ranyard, op. cit. (54), 76.

63 Anonymous [A. C. Ranyard], 'The Great Nebula in Andromeda,' *Knowledge* (1889), **12**, 108.

64 Anonymous [A. C. Ranyard], op. cit. (63), 108.



THE NEBULA IN ANDROMEDA

From a Photographic Enlargement by Mr. Isaac Roberts, *of his Negative of 30th December*, 1888.

Figure 3. 'The Nebula in Andromeda', *Knowledge*, **12**, March 1889, facing p. 108. Copyright The British Library. All rights reserved. PP.1447.bb.

bichromated albumen and a coat of chromated gelatin. Once prepared this plate was exposed in the usual way to the negative through a screen marked with a fine grid in order to break the tones into graded dots. The action of light hardened the gel, making it more resistant to water. After washing, the plate was coated with a mixture of water and glycerine. As the parts that had not been exposed to light absorbed water more freely than those that had, these portions resisted the fatty ink and so appeared lighter in proof. Each block produced between six hundred and eight hundred copies, but the process was slow because the gel required moistening every eighty to a hundred copies. Like all methods of photographic reproduction, the process was susceptible to the weather and much of the skill in working the collotype process lay in the determination of the correct proportions of gelatine and albumen to use according to the conditions.[65] The resulting images in *Knowledge* were striking: even though the collotype could only imitate the effect of the unbroken lines and tonal variation of the photograph through the fine dots rendered by the grid lines of the screen, it succeeded in reproducing a wide range of tonal contrasts, ideal for the subtle gradations of light in astronomical phenomena.[66] William Sheehan has suggested the collotypes were 'a sort of *hors d'ouevre* to the magazine's popularly written articles on science'.[67] But to produce such results each image was printed on a separate sheet of high-quality paper, distinguishing it from the rest of the letterpress.[68] More than simply illustrations, these images, included at no extra cost within *Knowledge*, were presented as desirable objects in their own right. Unsurprisingly, they were usually used to accompany Ranyard's astronomical essays. However, as the Andromeda example demonstrates, it was often unclear whether Ranyard was discussing astronomical phenomena in space or the representation of those phenomena in the images. Indeed, this imprecision as to what precisely was under discussion was made explicit in February 1890. Responding to positive comments about his reproductions in the wider periodical press, Ranyard then contributed an article to *Knowledge* about the collotype process that used as its examples the astronomical prints accompanying a separate article in that number.[69]

The use of collotype reproductions in *Knowledge*: the Great Nebula in Orion

In an article entitled 'The Great Nebula in Orion', published in May 1889, Ranyard attempted to enter a scientific debate on the basis of his collotype reproductions.[70] The article was accompanied by five images: one full-page reproduction of Isaac Roberts's photograph dated 4 February 1889 (Figure 4), a page containing reproductions of

65 In November 1889 the images in *Knowledge* were delayed due to the 'exceptionally dark' weather. See anonymous, untitled note, *Knowledge* (1889), **13**, 1. For the problems connected with the collotype process see anonymous, 'Difficulties in the collotype process', *British Journal of Photography* (1892), **39**, 450–1.

66 For details of the collotype process used in *Knowledge* see A. C. Ranyard, 'The collotype process and photo-engraving', *Knowledge* (1890), **12**, 71–2, 72. In this article Ranyard maintained that the crosshatch could only be seen with a hand magnifier.

67 Sheehan, op. cit. (14), 267.

68 See L. Nead, *The Haunted Gallery: Painting, Photography, Film c1900*, New Haven, CT and London, 2007, 211.

69 A. C. Ranyard, op. cit. (66), 72.

70 A. C. Ranyard, 'The Great Nebula in Orion', *Knowledge* (1889), **12**, 145–8, 145.

Figure 4. 'The Great Nebula in Orion', *Knowledge*, **12**, May 1889, facing p. 145. Copyright The British Library. All rights reserved. PP.1447.bb.

negatives with different exposure times from 16 February 1889 (Figure 5), a photographic reproduction of Lassell's drawing of the nebula produced in Malta in 1864 (Figure 6) and two structural diagrams prepared with Wesley's assistance. Ranyard exploited photomechanical reproduction to furnish images for the article in a range of media, but he began it with a defence of the photograph as a scientific document. Although the nebulosity in Orion was visible to 'any person with ordinary eyesight', Ranyard had already declared in his earlier article on Andromeda that 'the photographic record was far in advance of the most sensitive human eye'.[71] But it was not just the sensitivity of the photographic plate that warranted the superiority of photography. Drawing on his experience during eclipse expeditions and the production of the eclipse edition of the *Memoirs*, Ranyard also asserted its superiority on the basis of its impersonality as a record. He complained that when comparing drawings of faint objects like nebulae and coronae, 'one has to make allowance for the way in which each observer translates what he sees'. This was compounded in the case of skilled draughtsmen such as artists, who tended to interpret what they saw:

> Artists have not succeeded well in drawing coronas, though from time to time several artists of distinction have joined in eclipse expeditions with the object of making such drawings. They have generally devoted their energies to reproducing the general effect which has been soft and beautiful, though their pictures have been less truthful delineations of structural detail than those of many observers with less skilful hands.[72]

Observers 'with less skilful hands' were preferable, as they were passive, simply recording what they saw. By rejecting the aesthetic or scientific interventions that might be made by draughtsmen in favour of faithful reproduction, Ranyard echoed the arguments for the replacement of engravers with process for facsimile work. He thereby connected in a single mechanical process both the capture of the image and also its reproduction.

Ranyard's principal target for these remarks was Edward Holden's 1882 monograph on the nebula in Orion.[73] Illustrated with wood engravings, Holden's volume was similar to Ranyard's eclipse edition of the *Memoirs*, as it brought together a number of other people's work on the nebula but combined it with original research carried out by Holden at the US Naval Observatory in Washington between 1873 and 1880.[74] Holden had since become director of the Lick Observatory and used this data to support William Herschel's suggestion from 1783 that the nebula was subject to change.[75] Ranyard countered this by stating that although Holden 'had better opportunities of examining and weighing the original evidence … most people will prefer to wait until the evidence of change has been registered by the unerring eye of the camera'.[76]

71 A. C. Ranyard, op. cit. (70), 145; A. C. Ranyard, op. cit. (54), 75.

72 A. C. Ranyard, op. cit. (70), 145.

73 E. S. Holden, *Monograph of the Central Parts of the Nebula of Orion*, Washington, DC, 1882.

74 W. W. Campbell, 'Biographical memoir of Edward Singleton Holden', *National Academy of Sciences of the United States of America Biographical Memoirs* (1916), **8**, 345–72, 351. Osterbrock, op. cit. (14), 83–4.

75 See M. Hoskin, 'Herschel's investigation of nebulae', in M. Hoskin, *Stellar Astronomy: Historical Studies*, Chalfont St Giles, 1982, 125–36.

76 A. C. Ranyard, op. cit. (70), 145.

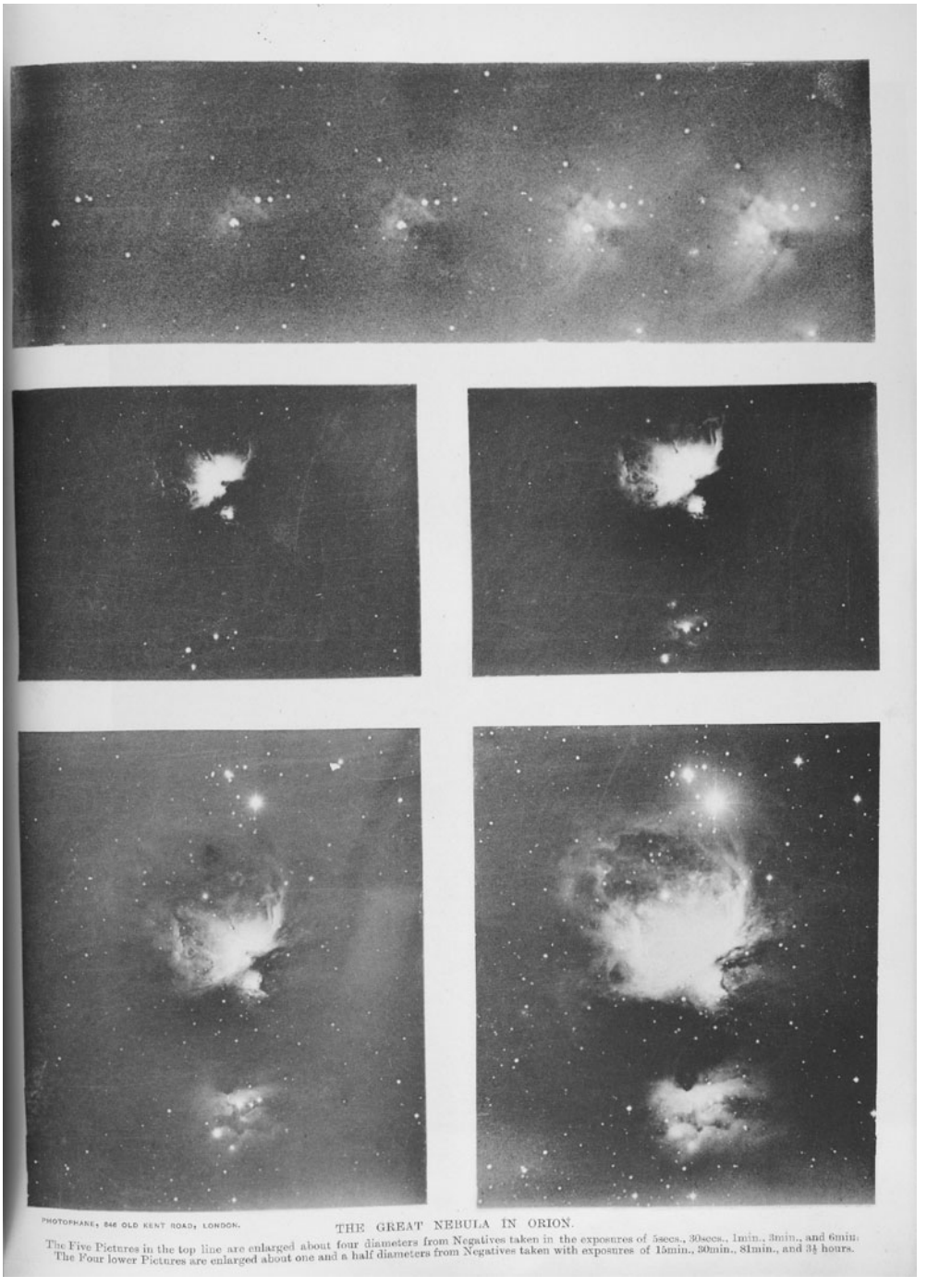


Figure 5. 'The Great Nebula in Orion', *Knowledge*, **12**, May 1889, facing p. 148. Copyright The British Library. All rights reserved. PP.1447.bb.

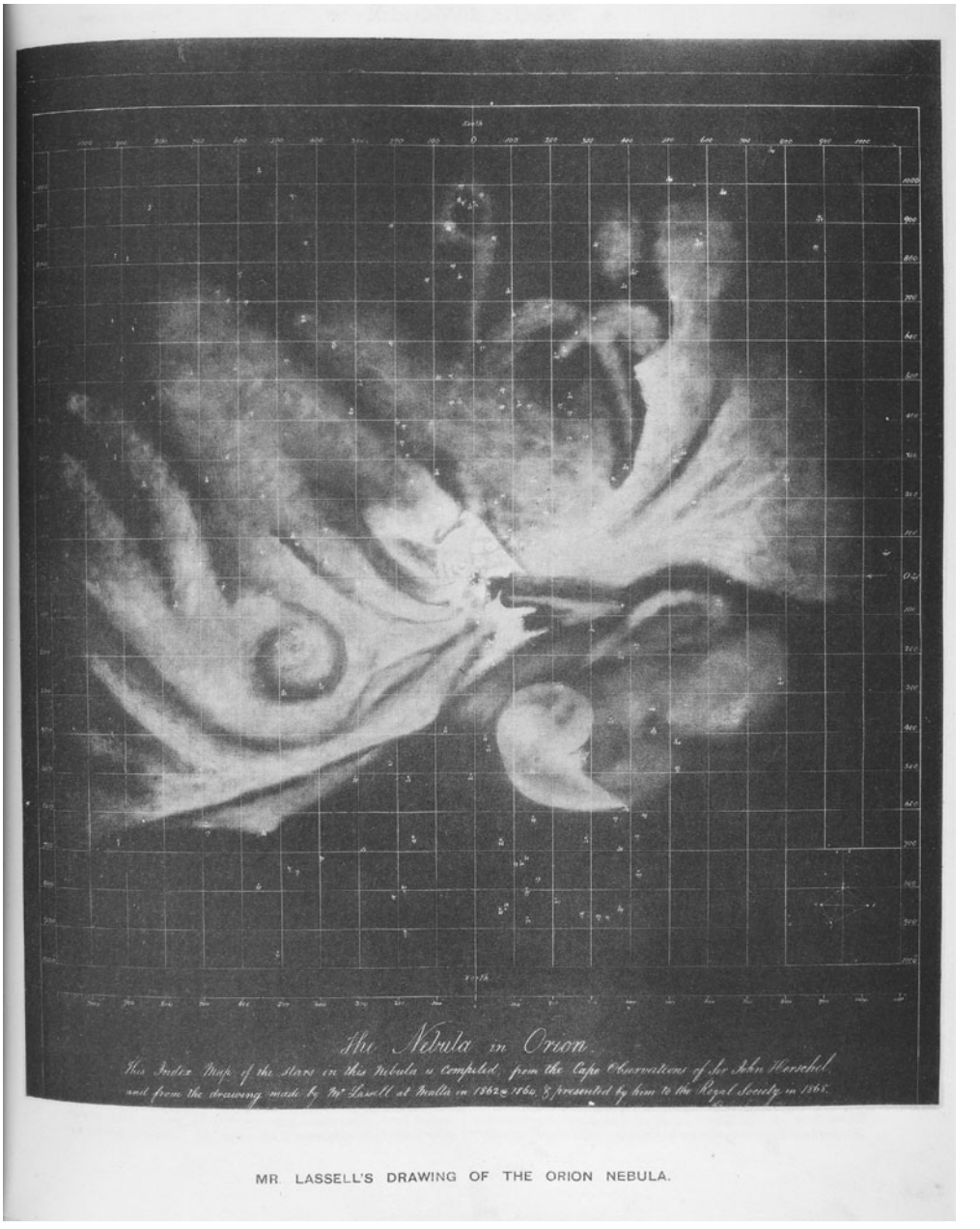


Figure 6. 'Mr Lassell's drawing of the Orion Nebula', *Knowledge*, **12**, May 1889, facing p. 148. Copyright The British Library. All rights reserved. PP.1447.bb.

Ranyard's comment was a little disingenuous. As both William Sheehan and Donald Osterbrock have noted, when Henry Draper succeeded in photographing the nebula in 1880, Holden conceded in the hastily written appendix to his monograph that

only photography would be able to provide conclusive evidence of such a change.[77] But what Ranyard provided in *Knowledge* was effectively a substantial afterword to Holden's book that surveyed the various photographs produced since 1880, complete with photographic reproductions and diagrams, in order to argue against any change in the nebula.

As in his earlier articles on Andromeda, Ranyard used the photographic reproductions to bolster the evidentiary status of the older reproductive techniques. But unlike the previous articles, this time Ranyard used the twenty-five-year gap between the images to make an argument about the nebula itself. The large reproduction of Roberts's 1889 photograph of the Orion nebula (Figure 4), one of 'the best results yet achieved', revealed similar structural detail to Lassell's drawing from 1864 (Figure 6). In discussing the images, all reproduced photographically for the readers of *Knowledge*, Ranyard disputed the evidentiary status of the wood engravings in Holden's book while covertly arguing for the accuracy of Lassell's drawing. He argued that judged by Roberts's photograph this drawing appeared to be 'the most faithful representation of the nebula which any draftsman has succeeded in producing'.[78] Despite already admitting that nebulae were extremely difficult to draw, Ranyard retrospectively proffered Lassell's representation as more accurate than either Holden's woodcuts or the drawings on which they were based, and did so solely on the evidence of Roberts's photograph. The many smaller reproductions demonstrated the variety of forms that images of the nebula could take. However, unlike the discrepancies between the woodcuts in Holden's book, the temporal narrative implied in these images rendered them as stages in a cumulative sequence that led up to the final image, which had the same exposure time as the full-page reproduction of Roberts's photograph that opened the article. The diagrams (prepared by Wesley) were 'index diagrams'. They served to bring out certain structural forms visible on the reproduced photographs. Ranyard's argument was that these forms appeared similar to those in coronae, implying that they might have similar origins. By referring to the reproductions rather than to the negative, Ranyard offered the page of *Knowledge* as scientific evidence in support of his claims.

The article provoked a flurry of letters. Keen to display the eminence of his correspondents to his readers, Ranyard printed extracts from these letters in *Knowledge* in July 1889. The first was from the astronomer W. H. Pickering, then at the Harvard College Observatory, who agreed about the coronal forms but referred readers to his own photograph, a lantern slide copy of which was deposited with the RAS.[79] The second was from Holden, who wrote to say that although Roberts had sent him a copy of his Andromeda photograph, he had 'not seen any copy until now of the Orion nebula'. Although Holden here accepted *Knowledge* as a source of the image, he insisted that only Ranyard, with 'the original negatives' before him, was 'in a position to judge of the analogies to groups of synclinal structure in the corona and in the nebula'.[80] So Holden accepted that Ranyard's arguments might be proven, but not on the basis of

77 Sheehan, op. cit. (14), 100; Osterbrock, op. cit. (14), 84.
78 A. C. Ranyard, op. cit. (70), 146.
79 W. H. Pickering, 'Extract from a letter from Professor W. H. Pickering', *Knowledge* (1889), **12**, 191.
80 E. S. Holden, 'Extract from a letter from Professor E. S. Holden', *Knowledge* (1889), **12**, 191.

the evidence as printed in *Knowledge*. By publishing these extracts, Ranyard advertised *Knowledge* as a transatlantic scientific journal at the expense of reminding readers that the authoritative scientific images still remained beyond its pages.

Both Holden and Pickering referred to the images in *Knowledge* but deferred to more authoritative versions elsewhere. This is important: whenever Ranyard represented his reproductions as identical to the negatives, he assumed an equivalence that transferred the authority of the astronomical negative or positive to the page of his magazine. Astronomical photographs had evidentiary status as they were prepared in controlled conditions that warranted their mechanical objectivity. However, as Jennifer Tucker has noted, such objectivity was also a product of reading the images.[81] When they were reprinted in a journal like *Knowledge*, not only were the processes that reproduced the image out of the control of those who made the originals, but they were being presented to the judgement of readers not able to recognize, and so validate, the correspondence between the image and the phenomenon that it represented. The photographic negatives were produced in closed sites of scientific practice, circulated amongst certain classes of audience and displayed in controlled environments. They were examples of what Bruno Latour has termed 'inscriptions'.[82] These objects, with 'the properties of being *mobile* but also *immutable*, *presentable*, *readable* and *combinable* with one another', were located at the tip of a 'cascade' that led back to and so defined the original phenomenon.[83] For Latour inscriptions participate in a process that ensures similarity through a culturally codified re-presentation. If scientists or readers generally accept the stability of the links in the chain, then they also accept the presence of the phenomenon despite the evident transformations and translations it has undergone to reach them.[84] Michael Lynch and Steve Woolgar have distinguished this from the notion of semblance, derived from Michel Foucault's *Order of Things*, in which each resemblance presumes 'a primary referent, an "original" that any "copy" renders in a partial and imperfect way'.[85] What was at stake in the reproduction of astronomical photographs was precisely this distinction. Although the negatives of astronomical photographs were widely accepted as inscriptions, the reproductions only resembled them. By treating them as equivalent in *Knowledge*, Ranyard was not only eliding this distinction, but doing so in a publication whose readers were not equipped to recover it.

This was demonstrated in the next issue of *Knowledge* in August 1889. In this issue Ranyard printed a letter from Isaac Roberts that stated that he had checked Pickering's lantern slide in the library of the RAS and, assuming that 'this slide represents some of his best work', could not find the nebulosity that Pickering claimed was upon it.[86] He

81 Tucker, op. cit. (36), 3.

82 B. Latour, 'Drawing things together', in *Representation in Scientific Practice* (ed. M. Lynch and S. Woolgar), London, 1990, 18–60, 23.

83 Latour, op. cit. (82), 26; original emphasis.

84 B. Latour, *Pandora's Hope*, Cambridge, MA, 1999, 58. For a similar argument about the mobilization and the act of looking at astronomical images see Nead, op. cit. (68), 219 and 226.

85 M. Lynch and S. Woolgar, 'Introduction: sociological orientation to representational practice in science', in *Representation in Scientific Practice* (ed. M. Lynch and S. Woolgar), London, 1990, 1–17, 7.

86 I. Roberts, 'Photographs of the Orion Nebula', *Knowledge* (1889), **12**, 211.

did find a light patch but a 'comparison with my negatives, however, shows that it is really a photographic defect or stain on the film'.[87] A skilled producer and reader of images and, as a Fellow of the RAS, with privileged access to them, Roberts reasserted the hierarchy between negatives and derivative copies and concluded by disputing the authority of images printed in the press:

> I am unable to judge what may be seen on Professor Pickering's original negative; but, on the other hand, he cannot judge of what can be seen on mine from the enlargements published in *Knowledge*. All negatives lose greatly by copying.[88]

Roberts's letter distinguished between the negative and the lantern slide, the inscription and the copy, and firmly located scientific authority beyond the reproductions in *Knowledge*.[89]

The use of collotype reproductions in *Knowledge*: E. E. Barnard, H. C. Russell and the photographs of the Milky Way

Despite the interventions by the producers of astronomical photographs, Ranyard continued to blur the distinction between the negatives and the reproductions in *Knowledge*. In March 1890 E. E. Barnard published an article in the *Monthly Notices of the Royal Astronomical Society* entitled 'On some celestial photographs made with a large portrait lens at the Lick Observatory' accompanied by two half-tone reproductions of the photographs inserted on a single page. Barnard captured these images with the Willard lens, a former portrait glass of six inches aperture and thirty-one inches focal length particularly suited to celestial photography due to its wide field and capacity to absorb light.[90] Ranyard wrote to Barnard through Holden, his supervisor at the Lick Observatory, to request copies to reproduce in *Knowledge*.[91] Holden responded positively on 15 April 1890 and, while corresponding with Barnard directly, Ranyard reproduced some of Holden's photographs of the Moon in *Knowledge* as a supplement to others he had published earlier in October 1889.[92] Holden had first announced Barnard's photographs of the Milky Way in the *Monthly Notices* for December 1889 but, as this article was unillustrated, it was not until Barnard's article in March 1890 that the images themselves were

87 Roberts, op. cit. (86), 211.

88 Roberts, op. cit. (86), 211.

89 Roberts, op. cit. (86), 211.

90 E. E. Barnard, 'On some celestial photographs made with a large portrait lens at the Lick Observatory', *Monthly Notices of the Royal Astronomical Association* (1890), **50**, 310–14, 312; Sheehan, op. cit. (14), 147, 151–3. For the history of wide-field astronomical photography see D. E. Osterbrock, 'Getting the picture: wide-field astronomical photography from Barnard to the Achromatic Schmidt, 1888–1992', *Journal for the History of Astronomy* (1994), **25**, 1–14.

91 These images were also produced by the Direct Photo Engraving Company – the same company Ranyard used for his collotypes. See Barnard, op. cit. (90), 310–14.

92 Royal Astronomical Society, Ranyard MS 3, 1–2. For the images of the Moon see A. C. Ranyard, 'The Moon as seen in the Lick Telescope', *Knowledge* (1889), **12**, 244–6; A. C. Ranyard, 'On the great bright streaks which radiate from some of the larger lunar craters', *Knowledge* (1889), **13**, 128–31. Ranyard also reproduced various photographs of the Lick Observatory and Mount Hamilton in November 1889. See A. C. Ranyard, 'On large telescopes', *Knowledge* (1889), **13**, 9–11.

published.[93] Ranyard eventually published Barnard's photographs of the Milky Way four months later in July 1890, inserting them on two separate pages and accompanying them with an article, 'On the Distribution of Stars in the Milky Way'.[94] Ranyard printed seven images in total: on the first plate was a full-page positive reproduction of Barnard's famous photograph of the Milky Way (Figure 7), and on the second plate were six smaller negative reproductions, two of the region around Andromeda, two of the region south-west of the Triffid Nebula, one of the Milky Way in Sagittarius and one of the Milky Way in Aquila (Figure 8). Of these only the two in the centre of the second plate had appeared in Barnard's March 1890 paper in the *Monthly Notices*, making *Knowledge* the only British source for the remaining images.

In the article, Ranyard referred to the 'exquisite photographic plates' and noted,

> They are well worthy of close examination, for they afford the reading public an opportunity of studying the structure of certain rich portions of the Milky Way, such as only the possessors of the largest telescopes have hitherto enjoyed. Indeed, I am probably right in saying that these plates show more of the structure of the Milky Way than can be seen by the eye with any telescope, for the gradations of brightness are accentuated, if smaller stars are not shown, and the eye can never grasp at one time, in the eye-piece of a telescope, as wide an area as that presented in these photographs.[95]

Although Barnard and Holden, in their respective papers in the *Monthly Notices*, had also stressed that the advantages of photography over observation at the eyepiece lay in its superior sensitivity to light and the possibility of wider fields of view, Ranyard politicized these advantages by also claiming to democratize the images. For instance, Ranyard claimed that the plates 'bear examining with a hand magnifier, when it will be seen that many of the regions which appear to the naked eye break up into a stippling of points corresponding to small stars'. On such a close examination, he wrote, 'many streaks and markings which at first sight might be taken for photographic stains or imperfections are really due to groups of stars'.[96] His use of the word 'plate' here was ambiguous, referring to both the photographic negatives and the reproductions in *Knowledge*, effectively eliding the evidentiary distinction between the two.

Thus Ranyard merged the inscription with *Knowledge*, asserting that the image in the magazine was equivalent to the negative, while surpassing the eyepiece as scientific evidence. The images seemed to justify Ranyard's previously tentative hypothesis about the structure of the Milky Way. He argued that they revealed details that suggested that the Milky Way was an aggregation of star structures in the galactic plane that could be seen one behind the other.[97] He also repeated his earlier claim that the dark spaces surrounded by stars on Barnard's photograph were dark bodies that absorbed light rather than simply gaps in the star clouds. Such an explanation, he argued, accounted

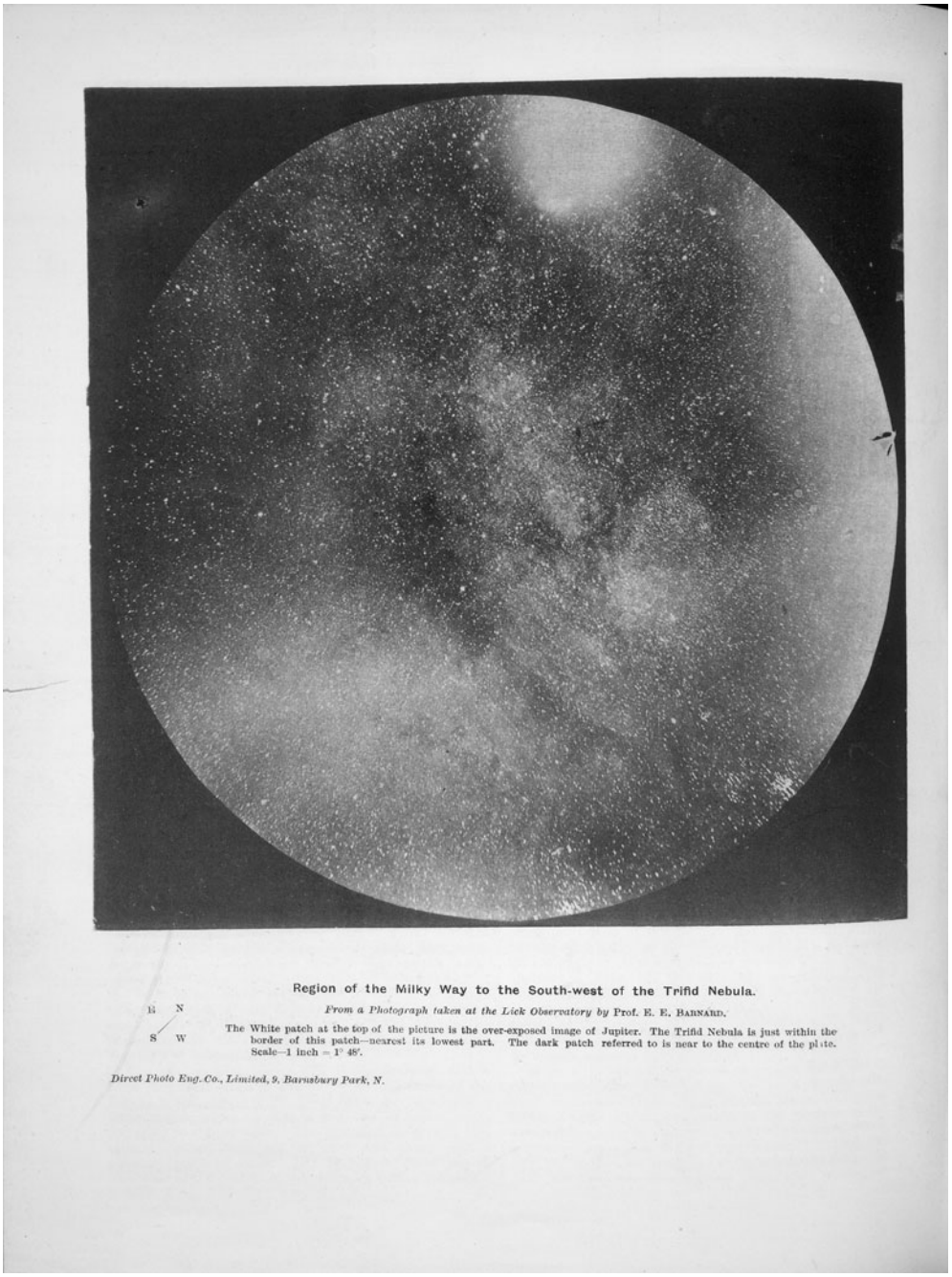
93 See E. S. Holden, 'On some features of the arrangement of stars in space', *Monthly Notices of the Royal Astronomical Society* (1889), **50**, 61–4; and Barnard, op. cit. (90), 310–14.

94 A. C. Ranyard, 'On the distribution of the stars in the Milky Way', *Knowledge* (1890), **13**, 174–5. There were problems printing the second plate and it was actually included in the August number.

95 Ranyard, op. cit. (94), 174.

96 Ranyard, op. cit. (94), 174.

97 Ranyard, op. cit. (94), 174.



Region of the Milky Way to the South-west of the Trifid Nebula.

From a Photograph taken at the Lick Observatory by Prof. E. E. Barnard.

E N
S W

The White patch at the top of the picture is the over-exposed image of Jupiter. The Trifid Nebula is just within the border of this patch—nearest its lowest part. The dark patch referred to is near to the centre of the plate. Scale—1 inch = 1° 48′.

Direct Photo Eng. Co., Limited, 9, Barnsbury Park, N.

Figure 7. 'Region of the Milky Way to the south-west of the Triffid Nebula', *Knowledge*, **13**, July 1890, facing p. 175. Copyright The British Library. All rights reserved. PP.1447.bb.

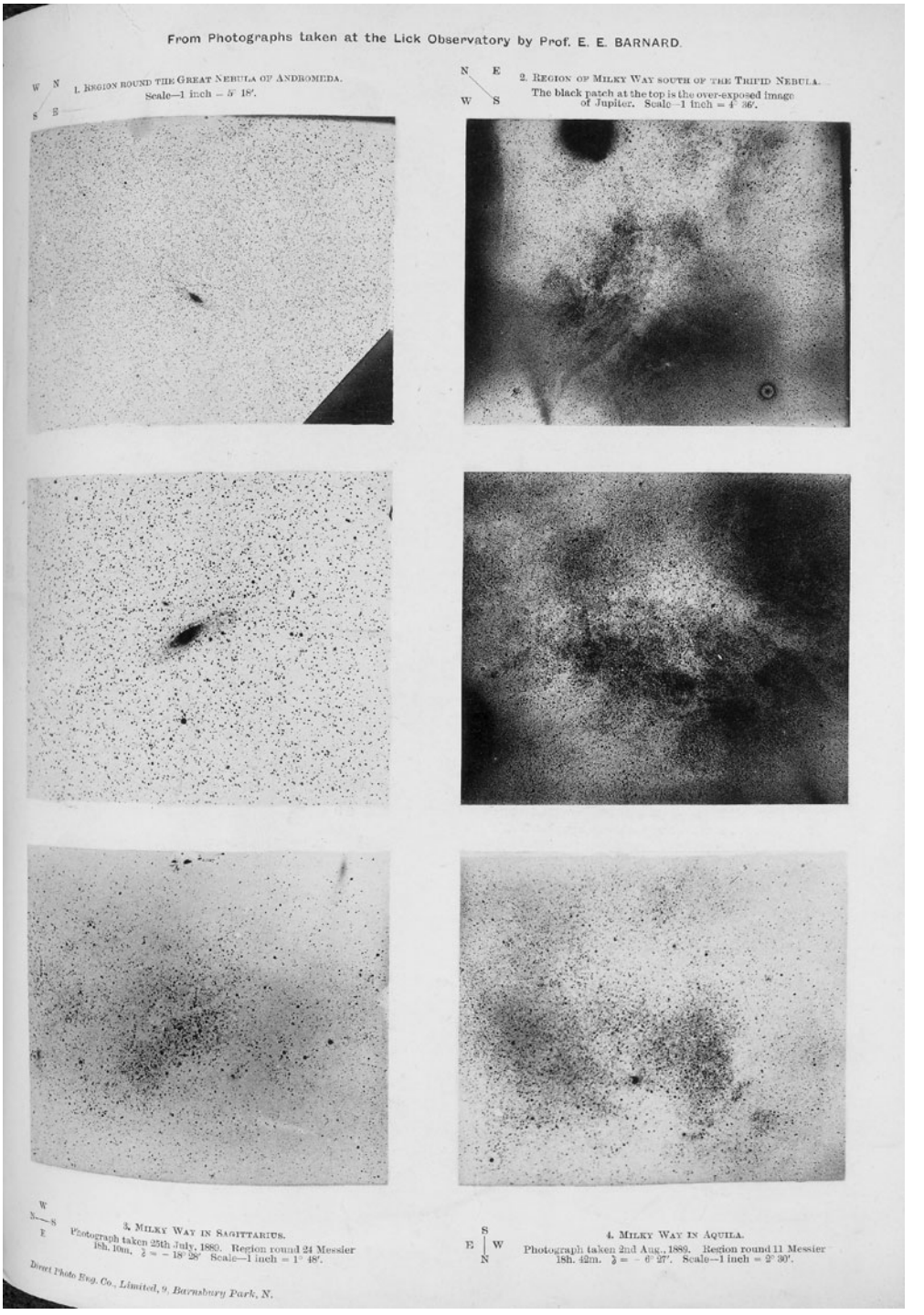


Figure 8. 'From photographs taken at the Lick Observatory by Prof. E. E. Barnard', *Knowledge*, **13,** August 1890, facing p. 186. Copyright The British Library. All rights reserved. PP.1447.bb.

for the lack of overall light in the night sky. Yet this hypothesis rested on Barnard's photograph, and Ranyard, in turn, relied upon its reproduction to demonstrate the existence of the structures that he saw upon it.

Both Ranyard's conclusions and the means through which he argued them were controversial. In his paper in the *Monthly Notices* for December 1889, Holden had insisted that Barnard's photographs were 'intended mainly as *diagrams*, to bring out the various patterns which are to be found in the arrangements of the star groups'.[98] Holden had warned that it 'will not do so well to simply reproduce the negative' as 'there is an art in examining an astronomical photograph which is akin to the art of observing with an astronomical telescope'.[99] Although aware that the structures he referred to on the image were difficult to see, Ranyard of course implied that at least some of his readers had the necessary skill to trace them. Barnard was very pleased with the reproductions in *Knowledge* but also refused Ranyard's conclusions.[100] In a letter to Ranyard dated 26 June 1890 Barnard wrote that he had considered Ranyard's theory but did not agree that the dark spaces were opaque matter absorbing light from the Milky Way.[101] Even the 'coal sack' – the dark object at 17 h 56′ δ –27° 50″ that Barnard used to guide his camera during the exposure – was 'simply a hole through the Milky Way like the many others in that region of Sagittarius'.[102] It was Barnard himself who, in an earlier letter dated 13 May 1890, not only directed Ranyard's attention to this object but also asked him if he would alert his readers to it.[103] However, he qualified this in the letter of 26 June 1890, writing that it was 'striking principally because of its smallness and its location in such a bright region' rather than because of what it implied about the structure of the Milky Way.[104] By keeping such remarks private, Barnard could express his appreciation of the reproductions while indicating his disagreement in a way that did not suggest publicly that Ranyard was ill-equipped to judge what he saw.

Barnard was prevented from producing any further images by necessary repairs to the Willard lens and delays incurred while it was remounted as the Crocker photographic telescope.[105] Ranyard, however, had other sources of images and, as he was dependent upon photographs for his astronomical speculations, published these in *Knowledge* instead. In March 1891 he printed four photographs taken by Henry Chamberlaine Russell, director of the Sydney Observatory (Figures 9 and 10). Russell had seen Barnard's Milky Way images in the July 1890 number of *Knowledge* and, in a letter dated 20 October 1890, offered Ranyard some of his own.[106] Ranyard moved quickly to get the images into print, publishing them in *Knowledge* eight months before the RAS

98 Holden, op. cit. (93), 64; original emphasis.

99 Holden, op. cit. (93), 63.

100 See Royal Astronomical Society, Ranyard MS 3, 17 August 1890, 1. Barnard was 'specially anxious' about the large reproduction of the region around 17 h 56′, δ –28°, but wrote 'it is most admirably done'.

101 Royal Astronomical Society, Ranyard MS 3, 26 June 1890, 1–3.

102 Royal Astronomical Society, Ranyard MS 3, 26 June 1890, 4.

103 Royal Astronomical Society, Ranyard MS 3, 13 May 1890, 4.

104 Royal Astronomical Society, Ranyard MS 3, 26 June 1890, 4.

105 Sheehan, op. cit. (14), 268–73.

106 Royal Astronomical Society, Ranyard MS 3, 20 October 1890, 1. Ranyard received the images with a letter dated 17 November 1890.

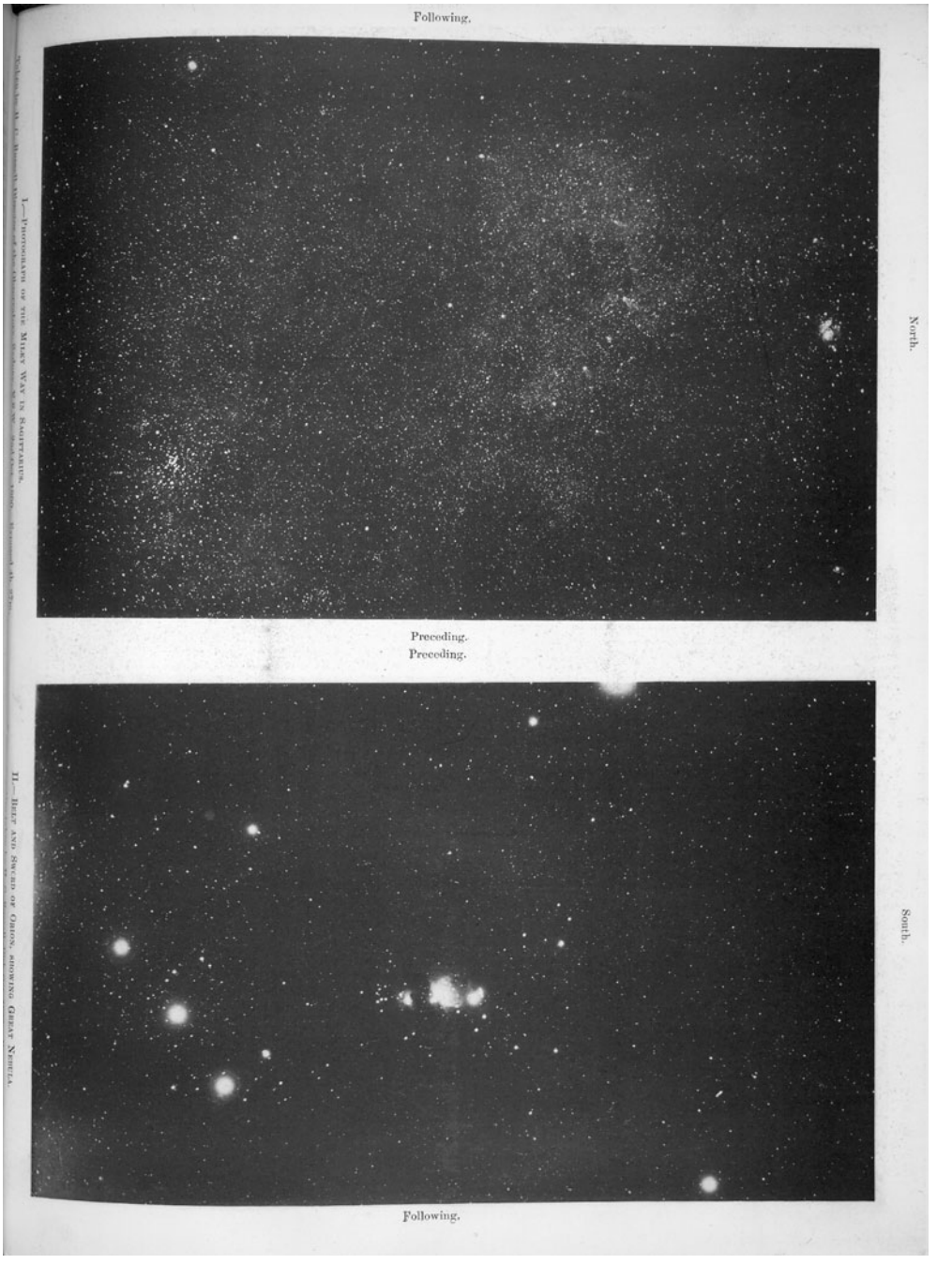


Figure 9. 'I. Photograph of the Milky Way in Sagittarius' and 'II. Belt and Sword of Orion showing Great Nebula', *Knowledge*, **14**, March 1891, facing p. 50. Copyright The British Library. All rights reserved. PP.1447.bb.

Figure 10. 'III. Photograph of the Nebecula Major' and 'IV. Photograph of the Nebecula Minor', *Knowledge*, **14**, March 1891, facing p. 51. Copyright The British Library. All rights reserved. PP.1447.bb.

published an unillustrated paper by Russell describing the same photographs.[107] The four photographs that Ranyard reproduced were the Milky Way in Sagittarius, the Great Nebula in Orion (both Figure 9), the Nebecula Major and the Nebecula Minor (both Figure 10). As with Barnard's photographs, Ranyard once again emphasized the quality of the reproductions, writing that they too would 'bear close examination with a magnifying glass'.[108] Ranyard was particularly interested in the Milky Way image as it had been produced under similar conditions and with similar equipment as Barnard's published in *Knowledge* the previous July. He drew his readers' attention to the differences between the two images, noting that Barnard's photograph showed 'much more of the nebulous structure of this region of the Milky Way than Mr Russell's'.[109] Ranyard was aware that this difference might be the result of the photographic process rather than of changes in the stars, so he attempted to pre-empt any objections to conclusions drawn from the images. Referring his readers to Barnard's image in *Knowledge* from July, Ranyard suggested that as the stars were the same brightness and only the nebulous patches had altered, the images must be equivalent. In response to the possible allegation that Russell's films were unevenly sensitive, Ranyard referred to another of his negatives, not reproduced in *Knowledge*, that lacked an impression of the passage of Mars. For Ranyard this second image, which he did not share with his readers, established the stability of both the film and the Milky Way by showing the same patterns of nebulosity at two different moments in time. He did concede that the differences might be due to different levels of stippling registered by the astronomers' respective plates or the impressions caused by different types of nebular light. However, if neither of these explanations were correct then, he argued, 'we may have evidence of the existence of a vast variable nebula which undergoes changes in the relative brightness of its parts with surprising rapidity'.[110]

Although Ranyard conceded that the differences between the images might have resulted from different photographic processes, he did not doubt the accuracy of the photographic method nor his own application of it when reproducing them in *Knowledge*. This permitted him to speculate that 'we have two independent photographs, and we seem to have evidence of a very rapid change in the brightness of the southernmost of these two star clusters'. If this were the case, he argued, it was reasonable to suspect that something was absorbing the light and, comparing the shape of star clusters to coronal forms, that this was evident as a resisting medium. Ranyard suggested that more photographs were necessary to confirm the variability of the nebula but, if true, then it would be necessary to posit 'the existence of forces travelling far more swiftly than light or electricity, and giving rise to the synchronous dimming or glowing of the light-giving matter'.[111] By stressing the need for further photographs,

107 H. C. Russell, 'On some celestial photographs recently taken at Sydney Observatory', *Monthly Notices of the Royal Astronomical Society* (1891), **51**, 39–43. The same issue contained a second paper by Russell, this time with a line process reproduction of a sketch of his mounting. See 'On an electrical control for driving clocks', *Monthly Notices of the Royal Astronomical Society* (1891), 51, 43–5.

108 A. C. Ranyard, 'The Milky Way in the southern hemisphere', *Knowledge* (1891), **14**, 50–1, 50.

109 Ranyard, op. cit. (108), 50.

110 Ranyard, op. cit. (108), 50–1.

111 Ranyard, op. cit. (108), 51.

Ranyard suspended endorsement of these professedly radical suggestions. But in doing so he also reiterated that photographs were the only source of evidence for galactic structure and implied that *Knowledge* was a suitable place in which to compare them.

The article provoked responses from both Barnard and Russell. The first was from Barnard. Ranyard printed his letter in *Knowledge* in May 1891. Barnard attributed the differences between the photographs 'entirely to the development of the negative'. Referring readers to an earlier article in the *Proceedings of the Astronomical Society of the Pacific*, the house journal of the Lick Observatory edited by Holden, he reminded them that 'the utmost care must be exercised in the development of the Milky Way pictures to bring out the cloud forms'.[112] Barnard cautioned that it 'is an extremely uncertain thing to compare two photographs like these, where one shows only feebly the cloud forms and the other shows them strongly and conspicuously' and, to address this, he overprinted his own image so that the cloud forms disappeared.[113] The resulting photographs were now 'identical in every respect', Barnard found, except 'several large stars … which are undoubtedly defects in [Russell's] plate'. He concluded with a final warning:

> I would remark here, as a caution, that it is extremely unsafe to judge of the actual relative brightness of different surfaces, such as the Milky Way presents, from photographs which have been treated differently in point of time and development. A partially brought out configuration will have in many cases, a decidedly different aspect from that of a carefully and thoroughly developed one.[114]

Ranyard reproduced the overdeveloped photograph 'as a printing-block by a photographic method' and inserted it in the middle of Barnard's letter. *Knowledge* now contained three different reproductions of the Milky Way: the first derived from Barnard's original Milky Way photograph that showed the cloud streams clearly, the second derived from Russell's photograph that did not, and a third derived from an overprinted image of Barnard's negative that now appeared identical to the second reproduction. Barnard's letter warned against drawing conclusions based upon a comparison of photographic negatives, because each might be affected differently during development, but made no comment regarding Ranyard's reproductions of the negatives in *Knowledge*. But in reproducing the third image with a photographic process, Ranyard both provided evidence that supported Barnard's warning about the negatives and at the same time cast doubt on the method that provided it.

In a note appended to Barnard's letter Ranyard maintained that the relative differences in brightness (as opposed to the overall effect) could not be explained by differences in development. However, his arguments were now contradicted by the three photographs reproduced in *Knowledge*. More damaging still, Ranyard also conceded that the large stars Barnard saw in Russell's photograph were probably not errors in Russell's original negative as Barnard had suggested, but had been introduced into the

112 E. E. Barnard, 'On the comparison of the photographs of the Milky Way in $\alpha = 17\text{H } 56\text{M}$. $\delta = -28^\circ$ in *Knowledge* for July 1890, and March 1891', *Knowledge* (1891), **14**, 93–4, 93.

113 Barnard, op. cit. (112), 93.

114 Barnard, op. cit. (112), 94.

collotype that Ranyard had made from it and sent to him. So not only was the comparison of original negatives rendered difficult by differences in photographic development, but the photographic conditions of reproduction could not accurately be depended upon. Although Ranyard was in the privileged position of being able to consider both astronomers' authoritative negatives, he was unable to marshal them in support of his interpretations, whether of the Milky Way or the representations of it in *Knowledge*.

Russell's letter to Ranyard was dated 6 July 1891 and Ranyard, in no hurry to print it, published it in *Knowledge* three months later. Russell agreed that care must be taken in developing Milky Way photographs but maintained that it was Barnard's images that were poorly developed. He disregarded suggestions that Barnard's plates were more sensitive or that Mount Hamilton provided favourable conditions for photography, and instead argued that Barnard had overdeveloped his original images, producing 'fog' on the plates that was 'almost impossible to distinguish from features of the Milky Way'.[115] Ranyard, in an editorial note affixed to the letter, sided unambiguously with Barnard, claiming that there was 'an intimate connection between the dark areas on Mr Barnard's photograph and the disposition of the stars that could not be due to chance, and the bright structures are altogether different in form from the patches in which fog shows itself on an overdeveloped picture'.[116] By citing his experience in reproducing images, Ranyard validated Barnard's negative, enabling him to use it as evidence for the existence of dark matter. Although the discussion was now firmly about the production of negatives, Ranyard was willing to countenance this to retain some photographic evidence of the dark patches, even though this necessarily deprived him of the more radical hypotheses that depended upon comparisons between reproductions made from them.

The dispute between Barnard and Russell in *Knowledge* exposed lingering doubts as to the evidentiary status of photography. Although both astronomers were able to link their images to astronomical phenomena, they emphasized that such a link was validated by the skill of the photographer. Reliant upon the images of others for his studies of the structure of the Milky Way, Ranyard continued to compare images and publish them in *Knowledge*. After the Russell and Barnard dispute, however, he had to account not only for the production of the original negatives but also for their accurate reproduction in the magazine. As this stage was out of the hands of the astronomers who produced the negatives and was in the hands of often financially insecure process companies, it remained easy for doubt to be cast on the published reproductions. Ranyard remained on good terms with both astronomers. He accompanied Barnard to France in the summer of 1893 and published more photographs from Russell between 1891 and 1894.[117] He also corresponded with the astronomer G. E. Hale, exchanging

115 H. C. Russell, 'On the comparison of photographs of the Milky Way', *Knowledge* (1891), **14**, 172–3, 173.

116 A. C. Ranyard, untitled note, *Knowledge* (1891), **14**, 173.

117 For Ranyard in France see Sheehan, op. cit. (14), 229–30; for Russell's photographs see A. C. Ranyard, 'The Lunar Appenines', *Knowledge* (1892), **15**, 31–2; for Ranyard's plans in 1894 see Royal Astronomical Society, Ranyard MS 2, 1–10.

photographs, scientific advice, gossip and even equipment. Hale was then at the Kenwood Astro-Physical Observatory in Chicago awaiting the construction of the Yerkes Observatory and encouraged Ranyard to visit the United States. This latter plan was never carried out: Ranyard was sick with cancer and died on 14 December 1894.[118] Throughout the last years of his life Ranyard persistently argued for the existence of dark matter on the basis of astronomical photographs and reproduced photographs in *Knowledge* as evidence.[119] However, despite his comprehensive network of astronomical contacts, he could not convince others of his theories through the medium of *Knowledge*. It was not until 1913, after producing astronomical photographs of the Milky Way for many years, that Barnard began to adopt Ranyard's suggestions as to the existence of dark matter.[120]

Conclusions

After Ranyard's death in 1894 the responsibility for the astronomical portions of *Knowledge* passed to Edward Maunder, the astronomer at Greenwich who had overseen the formation of the British Astronomical Association in 1890. In his 1900 history of the Royal Observatory, Maunder commented on the efficacy of astronomical photography. After describing the scientific impact of Roberts's Andromeda and Orion photographs, both reproduced in *Knowledge* in 1889, he maintained that they were, 'of course, of no utilitarian value, and at present they lead us to no definite scientific conclusions. They lie, therefore, doubly outside the limits of the purely practical, but they attract us by their extreme beauty, and by the amazing difficulty of the problems they suggest'.[121] When discussing the Orion Nebula in *Knowledge*, Ranyard argued that photography as a mechanical process contradicted precisely this scientific

118 Sheehan, op. cit. (14), 273–4.

119 See A. C. Ranyard, 'On the distance and structure of the Milky Way in Cygnus', *Knowledge* (1891), **14**, 188–90; A. C. Ranyard, 'Dark structures in the Milky Way', *Knowledge* (1891), **14**, 230–2; E. E. Barnard, 'The great nebulous areas of the sky', *Knowledge* (1892), **15**, 14–16; A. C. Ranyard, 'What is a nebula', *Knowledge* (1892), **15**, 191–2; A. C. Ranyard, 'What is a nebula?', *Knowledge* (1893), **16**, 10–12; A. C. Ranyard, 'The η Argûs region of the Milky Way', *Knowledge* (1893), **16**, 50; A. M. Clerke, 'The distribution of the stars', *Knowledge* (1893), **16**, 66–8; A. C. Ranyard, 'The η Argûs Nebula', *Knowledge* (1893), **16**, 69–70; A. C. Ranyard, 'What is a star cluster', *Knowledge* (1893), 16, 109–11; E. E. Barnard, 'On the probable encounter with Brooks' Comet with a disturbing medium on October 21 1893', *Knowledge* (1894), **17**, 34–5; A. C. Ranyard, 'Irregularities in the tails of comets', *Knowledge* (1894), **17**, 35–7; A. C. Ranyard, 'The structure of the Milky Way', *Knowledge* (1894), **17**, 61–2; A. C. Ranyard, 'Streams of stars in the Milky Way', *Knowledge* (1894), **17**, 101–2; A. C. Ranyard, 'What is a comet's tail?', *Knowledge* (1894), **17**, 113–5; A. C. Ranyard, 'Star clusters in the η Argûs region of the Milky Way', *Knowledge* (1894), **17**, 131–3; W. H. Wesley, 'On the distribution of the stars in space', *Knowledge* (1894), 17, 179–82; A. C. Ranyard, 'What is a star cluster', *Knowledge* (1894), **17**, 204–6; A. C. Ranyard, 'Photographs of the Milky Way and nebulae', *Knowledge* (1894), **17**, 226; E. E. Barnard and A. C. Ranyard, 'Structure of the Milky Way', *Knowledge* (1894), **17**, 253.

120 Sheehan, op. cit. (14), 274–5, 374–9. For Barnard differing with Ranyard see E. E. Barnard, 'Photographic nebulosities in the Milky Way', *Knowledge* (1894), **17**, 17. Barnard and Ranyard, op. cit. (119), 253.

121 E. W. Maunder, *The Royal Observatory Greenwich: A Glance at Its History and Work*, London, 1900, 301. For the aesthetic effects of astronomical photography see Nead, op. cit. (68).

redundancy.[122] If photographs were valid scientific resources on the basis of their means of production, Ranyard argued, then so too were their reproductions. As the dispute between Russell and Barnard showed, neither the production of photographic negatives nor their reproduction in the press were unproblematic mechanical procedures.

The evidentiary value of photographic images was predicated on their objectivity: as artefacts of a mechanical process they had no need for interpretation by an intermediary human agent. Yet this objectivity was in its turn warranted by those responsible for their production. Authoritative astronomical images were the products of well-resourced observatories staffed by experienced personnel and, crucially, were recognized as such by those who evaluated them. The reproduction of these images for use in the press necessarily introduced another transformative stage, often for the explicit purpose of disseminating the images beyond the usual networks through which they circulated. This had the effect of placing the reproduction and interpretation of such images beyond the scrutiny of the astronomical community, making it much more difficult to establish their fidelity to astronomical phenomena on the basis of the procedures and technologies that underpinned their production.

As the structures of the Milky Way were only visible in photographs, their value as evidence depended entirely on who made them and under what conditions. Without a referent with which to compare them, the process itself was the sole guarantor of their accuracy. As a member of the RAS, with good relationships with prominent astronomers around the world, Ranyard was in the privileged position of being able to evaluate a range of astronomical photographs and present his arguments to his scientific peers. But to make his arguments convincing for the readers of *Knowledge*, a commercial journal written primarily for a popular audience, Ranyard had to reproduce the images beyond their usual sites of production and consumption. When he treated his reproductions as reproductions, as images with more authoritative versions elsewhere, they remained uncontroversial. But when he made arguments on the basis of his reproductions, he enforced the continuity of the image regardless of its material transformation from negative to half-tone. In presenting the image in this way Ranyard attempted to trace an unbroken connection from the stars in the sky to the page of *Knowledge* on the basis of the photographic methods that underpinned all its stages. The warnings of Barnard, Holden, Roberts and Russell about the reproduction of photographs challenged the uniformity of these photographic methods by distinguishing between negative and half-tone, recognizing the former as scientific inscription and the latter as merely an inferior version of it.

Describing a popular audience in the preface to his account of the Royal Observatory, Maunder wrote,

> It was not the fault of the majority of his audience that they had not entered Greenwich Observatory, since the regulations by which it is governed forbade them from doing so. These rules are none too stringent, for the efficiency of the institution would certainly suffer if it were made a 'show' place, like a picture gallery or museum.[123]

122 Ranyard, op. cit. (70), 145.
123 Maunder, op. cit. (121), 5–6.

Even if Ranyard did not succeed in making *Knowledge* a scientific resource, he did give his readers a rare glimpse into discussions about scientific evidence of the sort that were usually restricted to the relatively closed spaces of specialist periodicals and learned societies. The disputes in the magazine might have enforced a distinction between the authoritative negative circulating among a coterie of experts, and the derivative half-tone reproduced across the press. But they also demonstrated how such attributes were allocated. The dispute between Russell and Barnard, in particular, demonstrated that negatives were not authoritative in themselves. Ranyard's support of Barnard allowed his negative to be a true inscription of the Milky Way, passively recording its traces, but relegated Russell's to a mere representation because the perceived flaws in its development had interfered in the process. The presence of such disputes, in addition to the reproductions themselves, distinguished the journal from its rivals in terms of scientific interest, credibility and value for money.[124] The half-tone process introduced a new visual repertoire into all branches of the press, including scientific publications. Despite Ranyard's efforts, *Knowledge* may have been a 'show' place, selling striking scientific images to its readers, but it also showed how such images were produced and, more importantly, how they might be read.

124 For instance, the RAS only began to sell photographs directly to the public in 1892 and, by 1895, there were still only twelve different images available. See Tucker, op. cit. (36), 204–7. In 1894 Isaac Roberts published *A Selection of Photographs of Stars, Star Clusters and Nebulae*, complete with fifty-three collotypes, for thirty shillings. At sixpence a month, with at least two collotypes per number, *Knowledge* was roughly half the price of Roberts's book, and offered a much wider selection of images than those available at the RAS.